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UNITED STATES DEPARTMENT OF COMMERCE
WOOD UTILIZATION

SAP STAINS OF WOOD AND THEIR PREVENTION

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WOOD
UTILIZATION

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UNITED STATES DEPARTMENT OF COMMERCE
WOOD UTILIZATION

SAP STAINS OF WOOD AND THEIR PREVENTION

BY

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University of Idaho

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The National Committee on Wood Utilization, established by direction of President Coolidge, comprises about 150 members, representing manufacturers, distributors, and consumers of forest products. Its object is to work for closer utilization of our country's timber resources. The committee, whose headquarters are in the Department of Commerce, Washington, D. C., works in close cooperation with a number of official and private organizations, notably the Bureau of Standards of the Department of Commerce and the Forest Products Laboratory of the Forest Service, Department of Agriculture.

FOREWORD

Sap stain and decay are among the most important causes of wood waste. These causes may be removed in most instances through proper piling, seasoning, and handling, although in some instances special treating methods may be required.

Doctor Hubert, formerly assistant pathologist at the Forest Products Laboratory, has for a number of years given this subject detailed study from a practical as well as a scientific point of view. He has demonstrated his interest by offering this manuscript to the National Committee on Wood Utilization for publication.

This bulletin is not only of interest to lumbermen, but also to anyone who uses wood and for whom the prevention of sap stain and decay is an important question.

The committee is greatly appreciative of the assistance Doctor Hubert has given on this important phase of wood utilization work. Acknowledgment is also made to the Forest Products Laboratory, John Foley, Dr. Thomas E. Snyder, Phillips A. Hayward, and others who have assisted in reviewing the manuscript.

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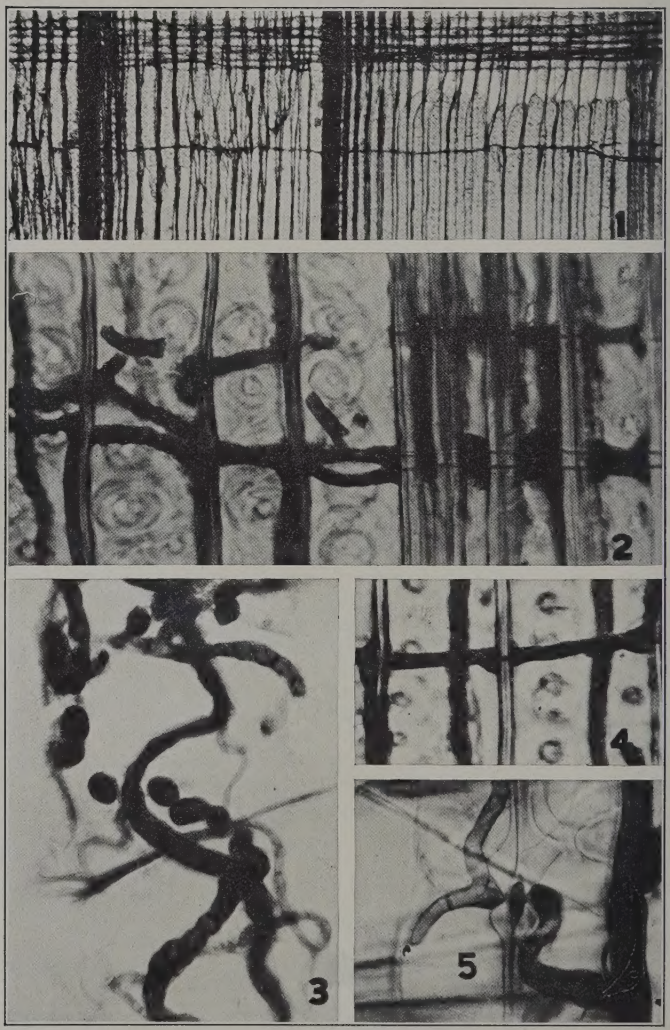
JUNE 15, 1929.



FRONTISPIECE.—Photomicrograph showing a hypha of the blue-stain fungus penetrating several tracheid walls in northern white cedar: *1*. Radial section stained with safranin. *2*. The extreme right-hand portion of *1* enlarged, showing the constricted hyphæ in the bore holes made in the tracheid walls. *3*. Photomicrograph showing sporelike development of hyphæ of *Lasiosphaeria pezizula* in persimmon wood; radial section, stained. *4*. Enlarged portion of the hypha shown in *1*. Note the swelling of the hypha at entrance and emergence and the constriction where passage is secured through the cell wall. *5*. Photomicrograph showing hypha of the blue-stain fungus passing through a bordered pit in the wood of loblolly pine. Tangential section stained with safranin and lichtgrün

SAP STAINS OF WOOD AND THEIR PREVENTION

INTRODUCTION

The staining and molding of lumber and other wood products have for many years been serious sources of loss to the lumber industry, which is one of the largest in the country (1926), employing 921,000 wage earners and producing products valued at approximately $4,000,000,000. Aside from their relation to the vital national question of maintaining an adequate timber supply, large losses of this nature can not be suffered by such an important industry without serious efforts being made to prevent them. Research offers the only means of obtaining the information necessary to the development of effective preventive methods, and the first step in this direction is a study of causes and the factors influencing them.

Most of the discoloration or stains which lower the quality and value of forest products are caused by certain minute organisms of the lower forms of plant life known as fungi and are very widespread. Another type of stain believed to be due to chemical reactions is not so common but nevertheless causes considerable loss due to degrade.

STAINS CHEMICALLY PRODUCED

Among the discolorations which apparently result from some chemical changes on the surface or within the wood are several brownish to yellowish stains in both pine and hardwood lumber. The exact nature of the changes is not known. Some of the stains appear in logs stored for a considerable period, while others develop in the lumber during kiln-drying or air-seasoning. The more important of these stains are:

STAINS DEFINED

Yard brown stain, which occurs as a yellow to dark-brown stain in air-seasoned white pine (*Pinus strobus*), sugar pine (*P. Lambertiana*), and western yellow (Pondosa) pine (*P. ponderosa*). In sugar pine the brown discoloration is often found just below the surface of the sawed boards and therefore is usually undetected until after planing.

Kiln brown stain is a yellow to dark-brown discoloration developing during the kiln-drying of sugar pine and western yellow pine. It is a serious factor in the grading of lumber and causes an annual loss that is very appreciable through lowering boards from the more valuable grades. The terms "scorch" and "kiln burn" have often been used to describe these two brown stains.

Kiln burn is a very dark browning, scorching, or actual charring of kiln-dried stock, caused by the use of too high temperatures.

FIGURE 1.—Brown sap stain in western yellow or Ponderosa pine lumber. This is a chocolate-colored stain caused by a fungus developing in the wood cells. It is usually found at the ends of boards since it enters the ends of logs and develops inward

Some types of kiln burn resemble closely the two stains previously described, but the color is more nearly uniform than in kiln brown stain. Wood showing kiln burn also is usually more easily dented than wood having any of the other brown stains.

Machine burn is a familiar type of brown discoloration found in finished stock. The scorched or burned areas develop when the progress of the piece through the machine is retarded and heat is generated by friction.

Water stain is a yellowish to dark-brownish surface stain on lumber. It is very common on the lighter colored woods upon which water has dripped or collected during seasoning or storage. It usually planes off readily.

DISTINCTION BETWEEN STAINS

The lumberman often finds it difficult to differentiate between stains produced by chemical action and some of those produced by fungi. For convenience, the term "brown stain" will be used to designate both kiln brown stain and yard brown stain, since their outward appearances are so similar. Kiln burn and machine burn are usually sufficiently different to be distinctive.

TABLE 1.—*Differences in gross characters between brown chemical stains and brown sap stain, which is caused by a fungus*

Charactertistic	Brown stain, kiln brown stain, yard brown stain	Brown sap stain
Western yellow pine, heartwood, sapwood	[1] x	x
Sugar pine, sapwood	x	x
Western white pine, sapwood	x	x
Jack, Norway, eastern white pine, sapwood	o	x
Incense cedar	x	o
Ends of logs or boards only	o	x
Throughout boards	x	o
Dark chocolate brown (auburn) [2]	o	x
Between Prouts brown and argus brown [2]	x	o
Somewhat uniform color areas	x	o
In streaks, irregular	o	x
White margin near ends and edges of boards and near juncture of heart and sapwood:		
Deepest color is next to white margin	x	o
In western yellow, jack, and Norway pines, rays often show deeper color (flecked)	o	x
Stain penetrates throughout sapwood	o	x
Stain often superficial or just below surface	x	o
Color appears in stored logs	o	x
Color appears during seasoning or storage of lumber	x	o

[1] Indicates presence of characters or stain, and o indicates absence of characters or stain.
[2] Ridgway. Color standards and color nomenclature.

The gross characters of these defects are tabulated in Table 1 and show considerable differences between brown stain and brown sap stain. The brown stains are commonly found in sapwood but also occur in heartwood and may extend throughout the length of the stock. The defect varies considerably, rarely shows flecking, is often superficial or just beneath the surface, and invariably shows a white margin near ends, edges, and surfaces of boards and near juncture of heartwood and sapwood. The discoloration always appears in lumber during seasoning or storage. Often confused with

these brown stains is a serious blemish known as brown sap stain (fig. 1), which occurs in the sapwood of western yellow and Norway pine, and less commonly in the white pines, as a rich brown to deep chocolate-brown discoloration. Many graders have been accustomed to look upon it as a stage of decay and to grade accordingly. As a matter of fact, this particular stain is caused by a fungus which acts similarly to the blue-stain fungus and frequently develops side by side with it (fig. 2). The dark uniform color penetrating deeply into the sapwood and the numerous darker flecks appearing in the region of the medullary rays aid in identifying this stain.

Brown sap stain is found exclusively in sapwood, where it extends from the ends of logs or boards. The color is a rich brown, shows a flecking in some woods, penetrates throughout the sapwood in spirelike streaks, and never shows a white margin near edges or ends of boards or in regions bordering the heartwood. The color makes its appearance almost invariably in the logs. Brown sap stain has been observed in various mills throughout Montana, Idaho, Washington, Oregon, California, the Lake States, and in British Columbia. It is primarily a log stain and has not been observed progressing in the lumber of air-seasoning piles. The fungus apparently enters the ends or barked portions of logs held in storage for too long a period during the warmer months. The result is a serious blemish, which is reported to cause considerable loss through degrade. Graders should exercise care in grading stock containing this blemish. Such boards may often be placed one grade higher if graded on the basis that the blemish is merely a sap stain and not a stage of decay. It is obvious that considerably greater losses will result if this sap stain is regarded as an early stage of decay rather than as a blemish resembling blue stain in its action upon wood. This unnecessary degrading of brown sap stain should be avoided.

ECONOMIC IMPORTANCE OF BROWN STAINS

Definite figures of the estimated loss from all types of brown stain are not available, but estimates have been made on the loss due to certain types. The brown stains not due to fungous action—kiln brown stain and yard brown stain—cause serious losses in western yellow pine and sugar pine in California, Oregon, Washington, and Idaho. From these two types the greater loss is in kiln-dried stock.

One mill reports that 35 per cent of its output of sugar pine is affected by brown stain. Another mill reports that out of a carload containing 23,000 board feet of sugar pine 11 per cent are rejected on account of brown stain. Western yellow pine graded as B select and better and selling at $105 per thousand board feet may be reduced in grade by brown stain to either C select at $90 per thousand or to D select at $75 per thousand. The same species graded as No. 3 clear at $70 per thousand may be reduced by this defect to No. 2 shop at $42 per thousand. Similarly, No. 1 shop at $65 per thousand may be reduced to No. 2 shop or to a box grade at $25 per thousand. This indicates that depreciation due to brown stain may amount to as much as $30 per thousand. These prices do not necessarily hold

FIGURE 2.—Brown sap stain *A*, and blue stain *B*, in air-seasoned western yellow or Ponderosa pine sapwood from Oregon

at the present time but do indicate the approximate relative values of grades.

Pratt,[1] in his study on the deterioration of lumber in the California region, shows 21 to 32 per cent of No. 1 and No. 2 shop degraded by brown stain in a total tally of 38,000 board feet.

On the basis of the total 1925 production of western yellow pine and sugar pine in the region where kiln brown stain and yard brown stain are common, an estimate of the degrade due to this defect places the losses at approximately $700,000. (See also work by Pratt.[1])

Estimates have not been made on the losses due to the brown-fungus stain, but those from this brown sap stain are higher than they should be, for in many cases this dark stain is classed as decay and for this reason causes greater depreciation than if classed as sap stain on a par with blue stain.

YARD BROWN STAIN

Yard brown stain is the particular type of brown stain which develops during air-seasoning or during storage. (Fig. 3.)

The color resembles closely that of kiln brown stain, but often the color does not show on the surfaces of rough boards, appearing only after planing. When planed the color differs little from that of kiln brown stain and shows the same narrow white margins at the ends and other surfaces of boards and near the juncture of heartwood and sapwood. The presence of the stain just below the surface makes this a troublesome defect in rough lumber, and graders of sugar pine and western yellow pine often scrape the surfaces with the sharp ferrule of the grading stick in order to expose the brown color. Expert graders claim to have a way of recognizing boards which contain this hidden defect. Usually the surface of the board directly over the discolored area shows slightly darker in the region between sapwood and heartwood.

At several mills in California and Oregon it is common practice to pile seasoned sugar pine on lath crossers during long storage in order to avoid "sweating" and brown stain. The "sweating" includes both development of mold and the exudation of sugarlike substances.

Yard brown stain occurs in 1-inch and thicker white pine (*P. strobus*) stock when air-seasoned or when stored for long periods. (Fig. 3.) This particular stock was observed at a northern Minnesota mill, and most of the brown stain appeared in the heartwood. When delivered to the consumer this stock was mistaken for kiln-dried material because it was claimed that it showed evidence of having been "burned" in the kiln.

Observations made at various California mills where considerable pine is air-seasoned disclosed only small amounts of yard brown stain in the thinner stock, but more in the stock 6/4-inch and thicker. An interesting observation was made on 6/4-inch air-seasoned western yellow pine. Especially on the upper surfaces and on the edges of this stock in the pile there appeared numerous yellowish gumlike drops, scattered and smaller toward the bark edge and denser and

[1] Pratt, M. B., The Deterioration of Lumber: Cal. Ag. Exp. Sta. Bul. 252, pp. 305-307; May, 1915.

larger toward the edge where sapwood joins heartwood. The appearance of gumlike substance on the surfaces and edges and its concentration in an area bordering the juncture of sapwood and heartwood closely resemble certain characteristics of brown stain.

FIGURE 3.—Upper, kiln-brown stain in sugar pine lumber. Lower, yard-brown stain in eastern white pine showing the dark-brown color developing in stock during prolonged air seasoning and storage

These drops appear on the surfaces of the sapwood portion of the board regardless of how resinous the adjoining heartwood may be.

In 1915 M. B. Pratt made a study of brown stain in air-seasoned sugar pine and found no fungus associated with the discoloration,

He came to the conclusion that the stain was of chemical origin and in some way connected with an oxidation process. "The presence of the sugary sap in sugar pine probably has something to do with the oxidizing process, resulting in brown stain, which is so common in lumber of that species. It is generally found as a distinct band between the heart and sap wood."

KILN BROWN STAIN

Kiln brown stain is one of the most troublesome and costly defects developing in kiln-dried stock of western yellow pine and sugar pine. (Fig. 4.) It has been reported as a defect in western white pine, but in this wood it is relatively unimportant. It has also been observed in incense cedar.

Kiln brown stain has been observed to some extent in the heartwood of both western yellow pine and sugar pine but is most commonly found in the sapwood, where its characteristics resemble closely those of yard brown stain. The color variations are similar, and the white margin at edges, ends, and surfaces of boards and near the juncture of heartwood and sapwood are very pronounced. The discoloration is usually more intense just behind this white strip.

MOISTURE TRANSFUSION THEORY

Whether the age and condition of the timber seem to have more influence upon the development of kiln brown stain than does the period of time during which logs are stored either in the woods or in the pond remain to be proved. Doctor Meinecke's [2] opinions of the former view and his further observations on kiln brown stain in western yellow pine, quoted below, are of interest.

> The entire appearance and distribution of the stain gives one the impression that the staining matter was not formed in situ but was contained in a liquid which had moved about in currents set up by the drying process and came to a standstill, accompanied by concentration, below the white outer layer and also when it reached the heartwood. The stain is due to a pronounced staining of the walls of the tracheids, including the ray tracheids. The cell walls in the clear layers, including the broken and bent fibers of the rough surface, are unstained.

CONCENTRATION OF STAIN

Apparently the concentration of color near the ends, edges, faces, and the heartwood region can be explained on the theory of moisture transfusion from the interior of the board to points near the surfaces. While the board is drying, the water solutions move toward the areas where evaporation is taking place. The greatest evaporation usually occurs at the ends, and here the color is deeper and more often observed. The white margin is often wider at this point. The heartwood, usually containing a lower moisture content than the sapwood, induces a rapid transfusion from the sapwood adjacent to it. In this case evaporation takes place somewhat the same as if the board were cut off at the juncture of heartwood and sapwood. This explanation may well fit the case in regard to the stained areas, but

[2] Meinecke, E. P., letter of June 18, 1923, on results obtained on field study of brown stain in western yellow pine at Susanville, Calif.

what of the white margins bordering the darker areas? It is my belief that these white areas represent the layers of cells in which free water was present only in the early stage of drying and later contained moisture in the form of vapor or at least under conditions

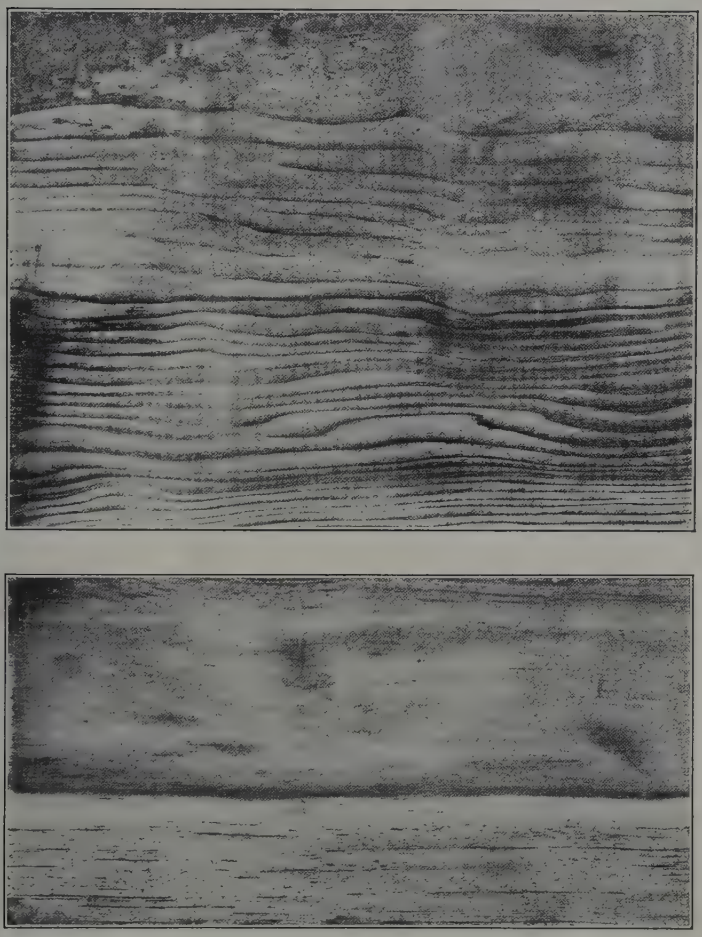


FIGURE 4.—Upper, kiln-brown stain in the sapwood of incense cedar showing the characteristic white margins at end of board. Lower, kiln-brown stain in the sapwood of western yellow pine. Note the white margin at end of sample and in the sapwood adjacent to the heartwood

unfavorable to the transportation of soluble substances. The concentration of color at the edge of this white layer indicates a deposition of the coloring matter out of solution at the point where the water changed to vapor and was therefore incapable of carrying it

farther. This would explain the hidden type of brown stain so common in both kiln-dried and air-seasoned stock.

A few simple experiments served to substantiate the transfusion and deposit theory. Small sticks of Sitka spruce 5 inches long were placed upright in test tubes containing a brown liquid collected from test tubes in which rot fungi had been grown on wood. The brown liquid formed a water-soaked area which extended up the sticks to within 2 inches of the tops. Here appeared a definite limit to the water-soaked area, which continued to become darker day by day as the water evaporated from this region and the brownish substance was left in the wood. At the end of the test dark-brown bands, darker at the upper margin, were formed near the edges of the water-soaked areas. Sticks of sugar pine 8 inches long were similarly tested, the liquid in this case being a sugar solution. In one other case the stick was shortened so that the end was an inch below the mouth of the tube. After allowing evaporation to continue for three days, the sticks were baked in an oven at 212° F. (100° C.), causing the sugar to turn slightly brown. A heavy deposit of sugar was detected at a point about 1 inch back from the exposed ends of the sticks projecting from the tubes, leaving the inch area at the tip with little or no sugar or discoloration. The other sticks showed heavy sugar deposits at the ends, this deposit extending to the tips of the sticks. The sugar solution constantly flowing to the top of the stick, where evaporation was taking place, slowly concentrated at this point.

TEST WITH BLOTTING PAPER

A similar test was conducted using 8-inch strips of white blotting paper. After two days' exposure the ends of the blotting-paper strips which projected beyond the mouths of the test tubes showed a layer of yellowish color, where the sugar solution had concentrated during evaporation. A heavy deposit of sugar was noted at the projecting ends of the paper strips.

Experimentally it was possible to cause brown stain to appear upon a particular surface. Pieces of green western white pine and western yellow pine sapwood were wrapped in heavy waxed paper with but one end of the pieces exposed. The wrapped pieces were dried in an oven at 212° F. for 48 hours. When removed all surfaces were bright, with the exception of the exposed ends, which showed a deep-brown stain behind the usual white margins. Evaporation took place almost entirely from the exposed ends, and it was here the brown color was formed during the latter part of the drying period. Other pieces were completely wrapped in the paper, having designs cut out on one side of the wrapping and then placed in the oven. Brown stain developed in the areas on the wood exposed by these stencil-like designs. These experiments were suggested by the fact that brown stain rarely develops in areas which are in close contact with crossers or stickers.

The so-called sugar in sugar pine is not a true sugar but a chemical compound called pinite or, more properly, pinitol. Collections of a white crusty exudation from the sapwood at the ends of sugar-pine logs when tested were found to have a saccharine taste. A similar

FIGURE 5.—What sap stain may do to a board. The sap gum board to the left is clear, without sap stain, while the one to the right is heavily blue stained. Both boards have been planed. The unstained board has been steamed prior to air seasoning while the stained board has been air seasoned without preliminary steaming

white powdery substance appears on the upper sapwood surfaces of sugar-pine boards stored on crossers in sheds for drying.

PREVENTION OF KILN BROWN STAIN

The entire problem of brown stain centers upon methods of prevention, since any bleaching or decolorizing process would appear to be too costly and cumbersome.

The majority of kiln operators interviewed believe that the kiln brown stain develops during the early part of the kiln schedule, possibly within the first two or three days. Observations made by A. Hermann, of the Western Pine Manufacturers' Association, indicate that, under certain conditions at least, the brown discoloration begins to show toward the end of the run. There appears to be a wide difference of opinion, however, as to the physical causes of the defect. Some believe it is due to an acid condition of the sap influenced by the temperatures and humidities of the kiln run. Some claim the so-called sugars in the sap are responsible for the discoloration after the heat of the kiln has caramelized this substance. Others do not attempt to determine the cause, but claim that high humidities and high temperatures are responsible, while low humidities and low temperatures are effective in preventing the defect.

At three of the mills visited, where it was claimed that the brown stain had been greatly reduced by modified schedules, it was observed that slower drying and therefore longer runs resulted. In most cases the modified schedules were not entirely successful when boards were used which had been cut from "old" logs. Kehoe [3] states that "old logs when decked in the yard are more subject to brown stain than when pond stored, and the older the logs the slower the drying schedule necessary at the start of the run, if brown stain is to be avoided or lessened." At the plant he cites a preliminary steaming is not used. At the end of the run a final conditioning of five hours at the highest relative humidity obtainable is then used to minimize casehardening. In the next 24 hours the temperature is increased from 150° to 180° and there held until a relative humidity of 8 to 10 per cent is reached throughout the kiln, at which point the stock is ready to be removed. Mr. Kehoe [3] believes "that high temperatures and the resulting rapid transfusion at the beginning of the run when the stock is green are the causes of brown stain in all western soft pines."

Morse [4] finds kiln brown stain more common in the top courses of edge-piled boards where the moisture content is also much lower than in the bottom courses.

He holds that dryness rather than moisture is a very important factor in producing brown stain and recommends high humidities in order to equalize the moisture content in all the boards and to prevent casehardening. Morse believes in stopping the run before the stock becomes dry enough to cause the brown color to appear.

If the boards are removed from the kiln while fairly moist, the substances dissolved in the water within the wood, though fairly concentrated at this stage of drying, may not be concentrated enough

[3] Kehoe, A. J., Prevention of Brown Stain: Timberman 25:62; May, 1924. Kiln-Drying Western Yellow Pine: Am. Lumberman, p. 68; May, 1924.
[4] Morse, G. A., New Theory of Kiln Stain: Timberman 27:74, 76; March, 1926.

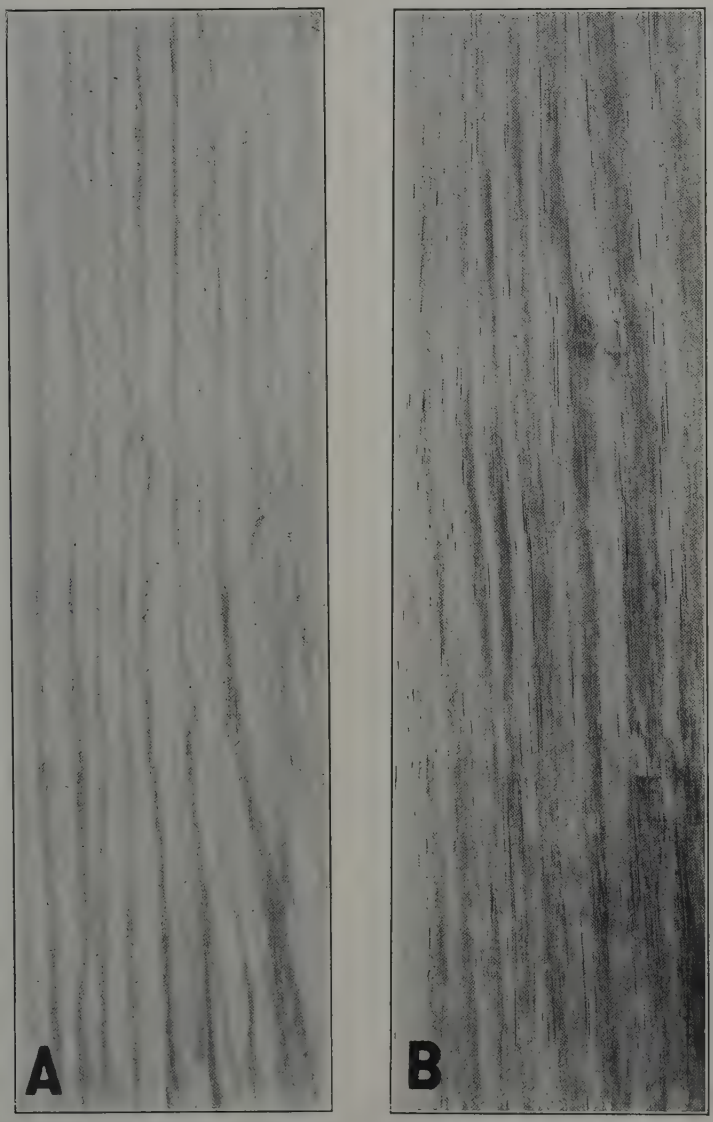


FIGURE 6.—*A*, Southern yellow pine board clear of stain. *B*, the same species of wood discolored by blue stain

to be altered in color by the action of heat. It appears also that as long as the majority of the heat is being used in changing the water in the wood to vapor no change in color takes place in the concentrated solution, but as soon as a certain low moisture content of the wood is approached sufficient heat is available to cause the material left in the wood to turn brownish in color.

From the facts already gathered it seems reasonable to suppose that slower drying during the early part of the run, resulting in a slower diffusion of the liquid containing the coloring matter, would prevent or reduce its concentration at the points of evaporation. A reduction of temperatures at the end of the run when the moisture content becomes low enough to allow the material in solution to concentrate would suggest itself as another angle of attack.

At some mills the practice is to cut the green stock thicker than usual and thus allow for considerable planing, which removes the outer brown-stained wood. At one mill in California, where the pine stock is given a preliminary air-seasoning of from 20 to 30 days and then kiln-dried, no brown stain develops. This observation, in connection with the fact that brown stain is less frequent in air-seasoned than in kiln-dried stock and that air-seasoned stock is subjected to slower drying at lower temperatures and humidities, appears to favor slow drying and low temperatures and humidities in kiln practices. Also, the temperatures are low at the time when concentration of the material in solution takes place. A great deal of experimental work needs to be done before a beginning may be made in the control of kiln brown stain. So long as the fundamental causes of this stain are unknown, control methods can not be expected to give uniform and satisfactory results.

BROWN SAP STAIN

The brown-colored stain due to fungous infection of sapwood was observed on pieces of western yellow pine box boards in shipments from a western State to Madison, Wis., and described as "scorch" of pine lumber.[5] The next collection came from Dr. J. S. Boyce, who sent samples of western yellow pine from Oregon showing brown sap stain and blue stain in the sapwood. It is common in jack pine (*P. banksiana*) and red pine (*P. resinosa*) of the Lake States and in western yellow pine throughout western Montana, northern and central Idaho, eastern Washington, Oregon, California, and British Columbia. It was observed in a few cases in sugar pine at California mills, and a stain closely resembling it was noted in western white pine at a large Idaho mill. One collection was made of this sap stain in pinon pine (*P. monophylla*) from Arizona. From the data so far gathered the causal fungus appears to develop best in species of the yellow or pitch pine group.

Field observations lead to the conclusion that this fungus enters logs held in storage for a considerable period. The stain is usually observed extending 1 to 4 feet inward from the ends of boards and from a few inches to 2 or 3 feet in the wood surrounding injuries or dead-branch knots. It has not been observed developing in lumber piled in the yard for air-seasoning.

[5] Hubert, E. E., Some Wood Stains and Their Causes: Hardwood Record, 52: 17–19. Illus. Mar. 25, 1922.

When thin sections of the brown-colored sapwood were examined under the microscope the wood cells showed a large number of tangled brownish threads developing within them. These threads were more densely grouped in the ray cells and account for the flecking observed as one of the characteristics of brown sap stain. No evidence was found that the fungus attacked the wood cell walls. This fungus apparently obtains its food from the cell contents in a manner similar to the blue-stain organisms.

The numerous brown stains[6] are difficult to distinguish one from the other, and because each type presents a different problem in prevention the characteristics of each need to be learned in greater detail. The following key, therefore, may prove helpful in identifying the various brown stains found in wood:

KEY FOR THE IDENTIFICATION, BY COLOR, OF THE BROWN STAINS IN WOOD

A. Stains found in both sapwood and heartwood, caused by agencies other than fungi ..... A–1; A–2; or A–3.
A–1. Yellow to dark-brown stains in air-seasoned stock .. A–1–a.
A–2. Yellow to dark-brown stains in kiln-dried stock .. A–2–a or A–2–b.
A–3. Yellowish to blackish brown stains, mostly superficial, due to machine burning or other causes .. A–3–a or A–3–b.

A–1–a. In eastern white pine, sugar pine, and western yellow pine, caused by chemical action in wood .. YARD BROWN STAIN.

A–2–a. In sugar pine, western white pine, and western yellow pine, caused by certain combinations of temperature and relative humidity during kiln-drying .. KILN BROWN STAIN.
A–2–b. In white pine and other woods, as a result of too high temperatures during kiln-drying, causing a scorching or charring of the wood ..... KILN BURN.

A–3–a. In many woods a dark-brown to blackish surface stain due to machine burning by saw or planer .... MACHINE BURN.
A–3–2. In many woods, particularly those of light color, a yellowish brown to blackish-brown surface discoloration in irregular patches and outlines due to the accumulation, condensation, or dripping of water on surfaces .. WATER STAIN.

B. Stains found in sapwood only, caused by fungi ..... B–1.

B–1. Chocolate-brown stain penetrating deep into sapwood of boards cut from old logs; streaked, irregular, flecked. In ends of boards or logs of western yellow pine, jack pine, red pine, and to some extent in the white pines ..... BROWN SAP STAIN.

STAINS PRODUCED BY FUNGI

The numerous stains caused by the class of fungi commonly known as molds vary in color from yellow, pink, red, purple, or brown to blue, green, and black. The molds in question are usually found on sapwood. They are characterized by cottony or downy—sometimes powdery—surface growths of various colors. Some of them cause no interior staining of the wood but by their variously colored surface growths produce blemishes which are readily planed off and in some cases can be brushed off. Other molds, such as the blue-stain fungi, cause stains deeper in the wood which can not be surfaced off. (Fig. 5.)

[6] Hubert, E. E., The Brown Stains of Lumber: Timberman, 27: 61; August, 1926.

The deeper stains are due to growth within the wood of minute threads of fungi. In some cases the wood structure is apparently stained by some coloring matter produced by these fungous threads. The mold fungi are very small plants which absorb their nourishment from the wood they inhabit, feeding principally upon the cell contents. As the threads grow they pass from one wood cell to another, usually through the wall of the wood fiber itself.

BLUE STAIN

Blue stain or blue sap stain is so well known that no special effort is here needed to familiarize lumbermen with this defect.

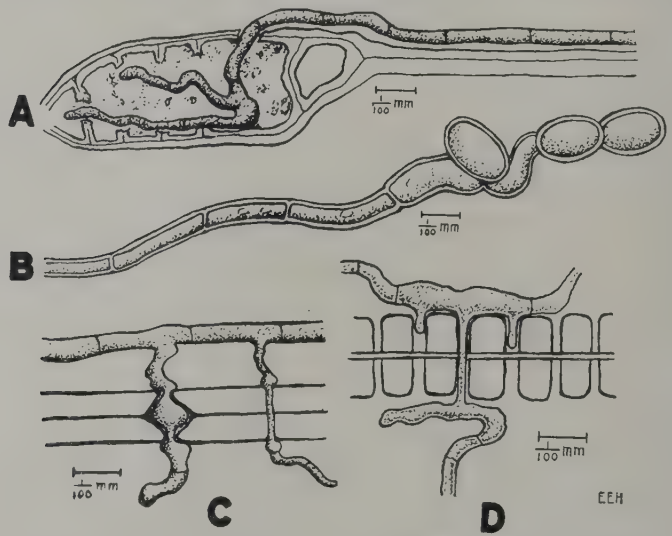


FIGURE 7.—Showing the threads of a blue-stain fungus in shortleaf pine, decomposing the medullary ray at *A*, and penetrating the cell walls at *C* and *D*, mainly through natural openings. Enlarged about five hundred times

Blue stain is often found in the same piece of sapwood containing brown sap stain. This grayish-blue to bluish-black stain develops, with but few exceptions, in the sapwood of a great many woods. Occasionally a bluish stain is found in the heartwood of Sitka spruce and a very few other species where moisture conditions are favorable. The blue sap stain establishes itself in the freshly cut log, develops in stored logs, and continues to develop in the lumber cut from such logs. It also appears with unbelievable suddenness and in great amounts in lumber freshly piled. Lumber and other wood products once seasoned and again moistened may also become blue-stained. A very peculiar and troublesome type of sap stain is often encountered in the seasoning of thick stock. This defect, which

will be described later, has been termed "interior blue stain" and differs widely from the subsurface types of brown stain.[7]

Blue stain (fig. 6) is common in the sapwood of a large number of hardwoods and softwoods, and the discoloration may appear as spots or streaks on the surface of a board or end of a log very soon after it is cut. Later, with the characteristically vigorous and rapid development of the fungus, the entire sapwood may be discolored. The telltale blue-gray color begins to show in the wood only after numerous very small threads of which the fungus is composed have reached a certain development within the cells. (Figs. 7 and 8.) When the threads, feeding on the contents of the cells and to a slight extent on

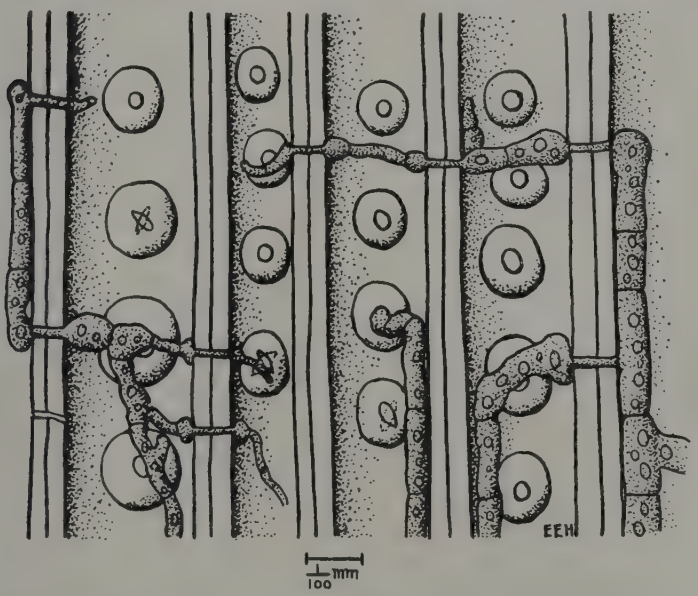


FIGURE 8.—Young threads of the blue-stain fungus in the wood cells of scrub pine, showing direct penetration of the cell walls. Most of the blue-stain fungi do not penetrate the walls in a direct manner but pass through the natural openings in the walls, called pits. In the lower center one thread is passing through a bordered pit. It is the presence of such threads within the cells that gives the blue color to the wood. Enlarged about five hundred times

the cell walls, reach a certain stage in their growth, fruiting bodies—comparable in some ways to the flowering part of the higher orders of plants—are produced upon the surface of the wood. (Fig. 9.) These fruiting bodies, which appear as tiny black specks upon the blued wood, when magnified are seen to resemble small black hairs or bristles swollen at the base. (Fig. 9.) From them minute spores are ejected (fig. 9) which, carried about by the wind or other agencies, germinate in new places and cause new infections. The above facts have an important bearing on the use of old blued crossers, as will be shown later.

[7] Hubert, E. E., Interior Dote in Elm: Hardwood Record, 54: 18–20; 1923.

Very little work has been done to determine the effect of the blue-stain fungi on the infected cell walls. Von Schrenk [8] discusses in considerable detail the effect produced on the wood tissues by a blue-stain fungus (*C. pilifera*) (Fr.) Wint. His drawings indicate that the fungus can readily attack and dissolve the walls between the individual cells of the medullary rays of pine wood. The inner walls of the rays are also shown to be affected, becoming thin and evidently weakened. He states: "The hyphæ are apparently able to puncture the unlignified walls here and there, but they stop at that point."

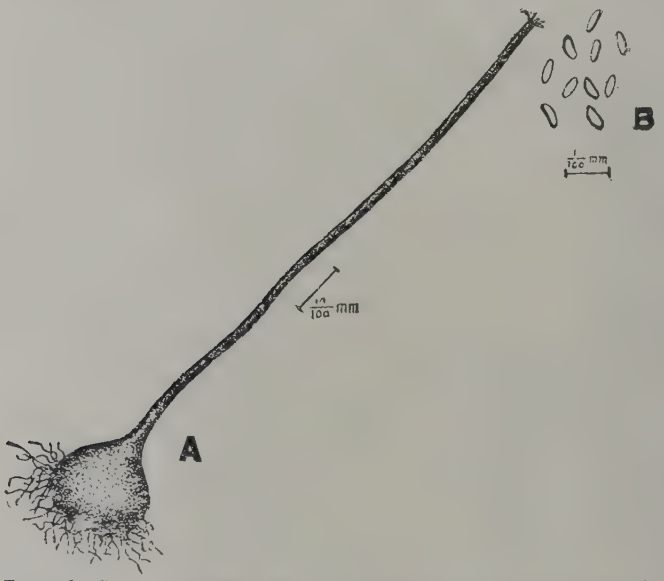


FIGURE 9.—Showing the flask-shaped fruiting body of a blue-stain fungus at *A*. Enlarged about one hundred times. The actual length is about five one-hundredths of an inch. At *B* are shown the minute spores ejected from the tip of this fruiting body and capable of germinating and starting new infections. Enlarged about eight hundred times

Münch [9] has brought out some interesting points concerning the blue stain of coniferous woods. He states that "The bluing fungi do not attack the wood substance to any great extent but live upon the contents of the parenchyma cells." He finds that these fungi can also become parasitic in standing living trees, provided the wood contains sufficient air and little water. He found that two of these fungi were capable of killing the living cells of coniferous wood and in part those of hardwoods.

[8] Von Schrenk, H., The Bluing and Red Rot of Western Yellow Pine: U. S. Dept. of Agri. B. P. I. Bul. 36: 1–35; 1903.
[9] Münch, E., Die Blaufäule des Nadelholzes: Naturw, Ztschr. f. Forstu. Landw. 5: 531–573, 1907; 6: 32–47, 297–323, 1908.

Hedgcock[10] studied the fungi accompanying various stains in the wood and found several species of *Ceratostomella* causing blue stain in both coniferous and broadleaf hosts.

In the blued wood of the hosts examined it was found that quite frequently the fungus threads penetrated the tangential cell walls of tracheids and fibers which were not in contact or adjacent to the medullary rays. (Figs. 7 and 8, pp. 16 and 17.) In one case where the sapwood of scrub pine was found heavily blued the examination of edge-grain sections showed a single young thread penetrating three cell walls. (Fig. 8, p. 17.) In edge-grain sections of blued shingles of northern white cedar as high as 64 cell walls were observed pene-

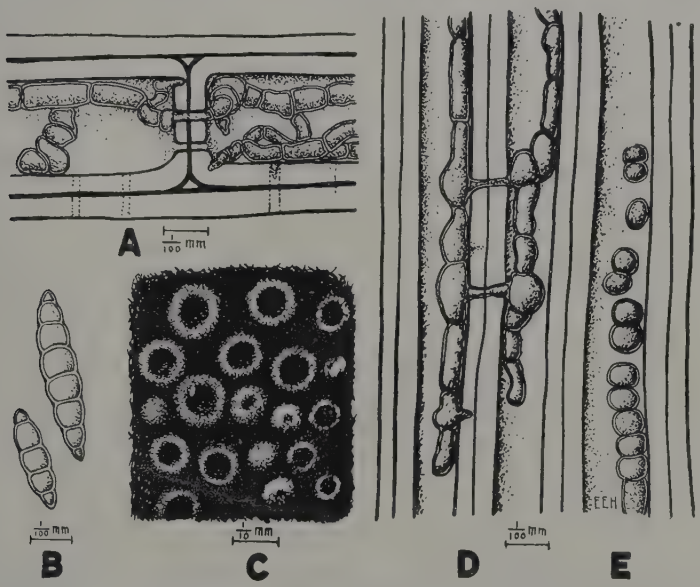


FIGURE 10.—At *A* and *D* the fungus threads of the olive black mold are seen penetrating the cell walls of persimmon wood. At *B* and *C* are shown the spores and the craterlike fruiting bodies of the above fungus enlarged about five hundred times

trated by a single thread. (Frontispiece, 1.) The threads are considerably constricted where they pass through boreholes in the cell walls, and swellings occur in the threads at the points of entrance and emergence. (Frontispiece, 2 and 4.) The young growing tip of these threads apparently is the source of the enzymes which dissolve the cell walls, since the boreholes are always of diameter corresponding to the size of the young threads. An exception to this is found in persimmon wood, where the fungus apparently is able to enlarge slightly the boreholes first formed by the young threads, since a variation in the diameter of the boreholes and amount of constriction is noticeable.

[10] Hedgcock, G. G., Studies Upon Some Chromogenic Fungi Which Discolor Wood: Report Mo. Bot. Gard. 17: 59–113; 1906.

In a recent work on sap stains issued by the Swedish Forestry Society [11] a belief is expressed that the threads force their way through the cell walls mainly by mechanical force and that the absence of small threads of the exact size of the boreholes in the cell walls indicate that penetration is not a direct result of enzymic action. It must be borne in mind, however, that in such cases the young threads are often colorless or nearly so and are therefore difficult to visualize unless special staining technique is used.

In the pines (fig. 7, *A*) and persimmon it was observed that the tracheid or fiber cell walls of the wood in close contact with certain threads are much thinner than the adjacent cell walls which had no threads in contact.

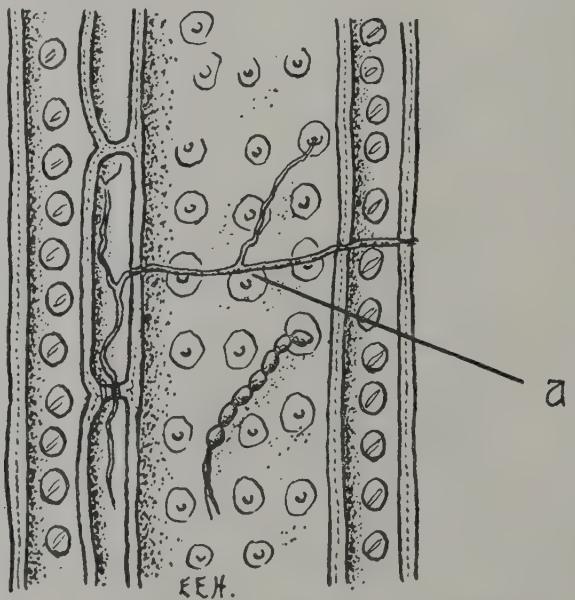


FIGURE 11.—The mycelium of the yellow-stain fungus (*P. divaricatum* group) in the wood cells of oak

More often the threads search out the simple and bordered pits and pass through these, the shape of the fungous thread conforming to the shape of the openng. (Fig. 7, *C*, and Frontispiece, 5.) In the case of simple pits the threads must dissolve the middle layer of the cell wall in order to pass through. In the bordered pits of coniferous wood the perforated torus membrane [12] forms but a weak barrier, yet a certain amount of tissue solution is necessary to sufficiently enlarge such minute perforations as already exist.

[11] Lagerberg, T., Lundberg, G., and Melin, E., Biological and Practical Researches into Bluing in Pine and Spruce: Jour. Swedish For. Soc. 23: 145–272; 1927.

[12] Von Schrenk, H., The Bluing and Red Rot of Western Yellow Pine: U. S. Dept. of Agri. B. P. I. Bul. 36: 1–35; 1903.

In the less lignified medullary ray cells the effect of the fungous attack is very pronounced.[13] The cell walls between the ray cells are completely decomposed, the radial walls of the ray becoming very thin and broken, so that there is less than a shell or framework of the ray left. (Fig. 7 *A*.) The medullary rays, in certain cases, present a seriously decomposed and evidently weakened aspect.

CULTURAL CHARACTERS

During the first few days of the development of blue-stain (*Ceratostomella* and *Graphium* sp.) threads in artificial media or on wood blocks they are observed to be colorless. Soon the mycelial growth begins to darken in color, and the cultures on malt agar, for example, turn almost black. Von Schrenk[14] states that cultures of *Ceratostomella pilifera* on pine blocks show the threads to be colorless during the first four to five days. At the end of this period they turn from colorless to a brown color. In from 7 to 9 days young fruiting bodies are produced, and spores are ejected from these in from 12 to 18 days. Full maturity is reached in 21 days. This would indicate that a new crop of spores could be expected every 18 to 21 days under conditions favorable for growth.

As we learn more about the wood-staining fungi we find new ones to add to the growing list. Recent investigations in this country and abroad have already brought many new species to light. A few of the most important stains causing loss through degrade are briefly discussed.

GRAYISH-OLIVE STAIN OF HARDWOODS

This stain was first described[15] as common on stored railroad ties cut from beech, red gum, and persimmon. It has also been found in black gum pulp logs. The stain caused by this fungus, *Lasiosphaeria pezizula* (fig. 10), resembles somewhat the blue stain in sap gum caused by other fungi but differs in that it is grayish olive in color instead of bluish gray. It stains both heartwood and sapwood and is usually found penetrating from 1 to 4 inches the cut ends of ties or logs. As in the case of blue stain, the presence of the fungous threads in the wood tissues is responsible for the discoloration. The majority of the hyphæ are found in and near the medullary rays, which are slightly altered by the attack. Decomposition of the ray cells is not as extensive as that produced by the blue-stain fungi. Cells in the neighborhood of the rays are usually invaded through the bordered pits and the simple pits. Penetration of the cell walls of the wood fibers is occasionally noted, and the hyphæ are always constricted when passing through the boreholes. (Fig. 10.)

The surface of the wood infected with this organism usually bears a layer of olivaceous-black mycelium, with occasional clusters of small, closely grouped fruiting structures which, when old, collapse and resemble minute craters. (Fig. 10.) The color and shape of

[13] Hubert, E. E., Notes on Sap-Stain Fungi: In Phytopath. 11: 214–223; May, 1921.
[14] See footnote 8.
[15] Humphrey, C. J., The Decay of Ties in Storage: Proceedings American Wood Preservers' Association, 16: 217–250, pls. 1–8; 1920.

these fruiting bodies and the 1 to 7 celled spores they contain (fig. 10) readily distinguish this fungus from the blue-stain fungi.

Tests made to determine the sterilizing effect of heat upon the organism within 3/4-inch oak boards showed that it could resist a temperature of 170° F. for 24 hours at a relative humidity of 35 to 65 per cent. No doubt the formation of spores within the wood tissues, a characteristic of this fungus, had something to do with this unusual resistance to killing by heat.

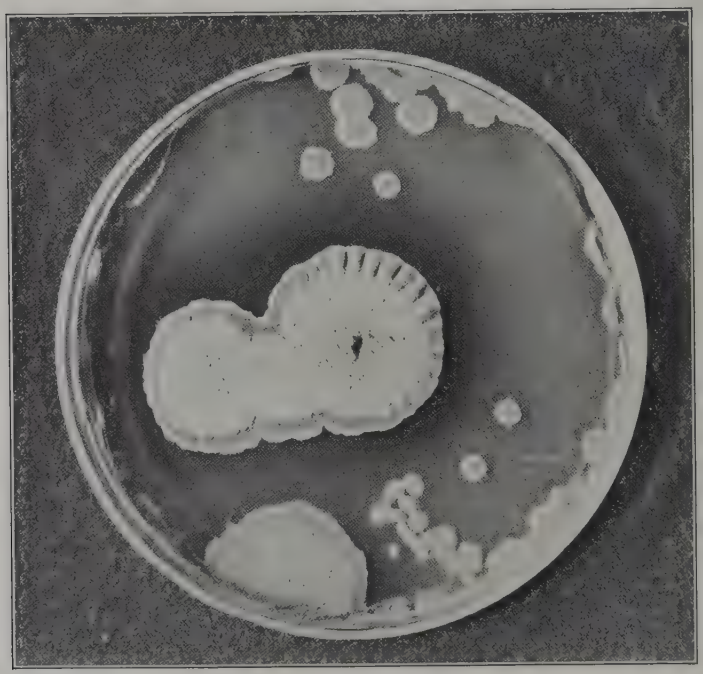


FIGURE 12.—A 4-day-old culture of the yellow-stain fungus (*P. divaricatum* group) on malt agar

YELLOW STAIN OF HARDWOODS

The principal loss due to this stain is in the discoloration of the finished product and has caused considerable uneasiness when discovered in oak stock used in the manufacture of airplane propellers.[16] A study of the fungus in relation to the strength properties of yellowed oak has indicated that the mechanical properties of the wood are but slightly affected.

Yellow stain is often found in the products manufactured from hardwoods. The stain develops in the wood during the period

[16] Colley, R. H., Wilson, T. R. C., and Luxford, R. F., The Yellow Stain Fungus and Its Effect on the Strength of White Oak: Final report. Forest Products Laboratory; 1924.

following the cutting of the tree and before the wood is worked up into the finished product. Improper storage of logs, lumber, or other wood products under conditions favorable to fungous growth may cause this stain to develop. A moldy appearance of the stock may be the first symptoms. Later the wood may show the characteristic yellow discolorations.

FIGURE 13.—Drawing showing fruiting stalk bearing spore chains (+300) and spores highly magnified (+1,600) of the yellow-stain fungus

The stain has been observed in birch veneer and airplane stock, hickory and maple handles, in oak laminations used in airplane propellers, in oak wagon felloes and spokes, and in oak lumber.

The stain is of a pale yellow color sometimes difficult to detect, usually in streaks or irregular areas, and is most easily detected when the wood is freshly surfaced. The fungus is found in areas of

the wood showing very faint to no discoloration. The stain often penetrates deep into the wood and can not be surfaced off. Thin sections of the yellowed wood observed under the microscope show numerous minute colorless fungous threads within the wood cells, occasionally penetrating the cell walls. (Fig. 11.)

Artificial cultures (fig. 12) using fragments of the yellowed wood produce a fungus which is moldlike in character, olive buff in color, and which grows rapidly under proper moisture conditions.

Taxonomic characteristics place the fungus in the *Penicillium divaricatum* group. (Fig. 13.)

RED STAIN OF BOX ELDER

A disease of the box elder characterized by a bright red stain in the wood has been under observation since 1920.[17] The stain is very frequently met with and, therefore, popularly believed to be a fairly reliable character for the identification of box elder wood. This red-stained wood has been found in many places in the United States, and what appears to be the same thing has been reported in a few places in Europe.

The discoloration is found in all parts of the tree, from the roots to the smaller branches. (Figs. 14 and 15.) Its vivid color lends some poetic faith to the belief held by the ancient Greeks that it represented the heart blood of the dryads, tree spirits, or wood nymphs, who were killed with the cutting of the tree. Scientific curiosity and the use of the microscope have disclosed this "dryad blood" to consist of something very different.

It has been found that this red discoloration of a light coral red to hellebore red or carmine color, common in heartwood and to some extent in sapwood, is due to the presence in the wood of a soluble red pigment produced by the colored threads of a fungus new to science and named *Fusarium negundi* Sherb. This fungus develops within the wood and derives its nourishment therefrom, but no evidence has yet been found to indicate that it decays the wood.

It is classed as a wood-staining organism.

The fungus appears to be weakly parasitic, since it is found developing in the sapwood of living trees, following entrance through wounds principally caused by sapsuckers—birds resembling the well-known woodpeckers. The sapsuckers appear to be agents in spreading the disease from different parts of a tree or from tree to tree.

Associated at times with the red-stain fungus in the same tree are to be found various rot-producing fungi. This necessitates caution in the use of red-stained wood where strength and durability are important.

The geographical distribution of the red-stain disease is assumed to coincide with the range of the box elder. It has been found in many places in the United States, and what appears to be the same disease has been reported in a few places in Europe.

As means of reducing the spread of the red stain and as a preventive measure in case the organism develops greater parasitic tendencies, sanitary measures in regard to the proper care of wounds are suggested for shade trees; and for forest trees the burning of

[17] Hubert, E. E., The Red Stain in the Wood of Box Elder: Jour. Ag. Research 26: 447–457; 1923.

FIGURE 14.—Transverse sections of a box-elder branch 2 inches in diameter showing the central portion stained by the red-stain fungus (*Fusarium negundi*)

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FIGURE 15.—Transverse section of box elder cut down in November, 1922, showing the heart rot of *Fomes applanatus* in the central heartwood; surrounding this is a dark band of red stain with five projecting areas all halting abruptly on the same annual ring. The sapwood shows scattered individual infections by the red-stain fungus which entered through injuries produced by sapsuckers. At the division line between the two annual rings last formed are found eight of these infections. One of these injuries had not been healed and the direct relation is shown between the red-stain area and the cavity in the bark and cambium, produced by the bird

affected slash and the rapid handling of infected logs are believed to be of value.

GRAYISH-BLACK STAIN OF ASH

Dark-tan to grayish-black streaks in white ash (*Fraxinus americana*), pinkish-colored areas in yellow poplar (*Liriodendron tulipifera*), dark-colored streaks in red gum and basswood, and brownish-black areas in eastern hemlock (*Tsuga canadensis*) have been found to contain a fungus (*Torula ligniperda*) which is decidedly different from most stain-producing organisms.[18] This fungus is commonly found in the heartwood and is a common cause of blemish in white ash. Tests made to correlate the color with the toughness strength [19] [20] indicate that visual inspection can not be relied upon to separate the infected from the uninfected stock. Toughness tests and specific-gravity determinations are considered of value in determining the value of the stock for commercial use.

The threads of this fungus in the wood are small and colorless, usually following the hollow of the cells but occasionally penetrating the cell walls. A characteristic spore formation consisting of dark ovoid spores borne in chains is often found within the wood cells. The wood structure is apparently little affected by the presence of this fungus, and such wall penetrations as were noted were few and difficult to determine. In hemlock the fungus is usually found associated with a brown cubical rot of the heartwood, the Torula infected area bordering the outer limits of the early decay.

"MINERAL STREAK" OF MAPLE

A greenish to olive discoloration is frequently noted in maple stock cut in the hardwood region. This stain is known locally as "mineral streak" or "mineral stain" and is supposed to be caused by the absorption of iron or copper salts through the roots of the living tree. (Fig. 16.) It is a troublesome defect and is found causing depreciation in a variety of wood products. In thick stock, kiln-dried for automobile construction, the greenish areas almost invariably develop "honeycomb" while the surrounding uncolored areas remain unchanged. (Fig. 16.) Again, in veneer stock cut for butter baskets and other products the green streaks are found to check readily and so cause a high percentage of "rejects." Millmen all agree that the greenish areas are harder than normal wood and that the edges of tools are prematurely dulled when cutting this kind of stock. Very often the saw will "heat up" when it begins cutting its way through the discolored areas. This fact lends color to the belief that an infiltration of "mineral" is responsible for the defect.

Microscopical examinations of the discolored areas have disclosed minute colorless threads of a wood-inhabiting fungus within the wood cells. Cultural tests using fragments taken from air-dried stock have shown a fungus developing from the greenish pieces of

[18] Siggers, P. V., Torula Ligniperda (Willk) Sacc. A Hyphomycete Occurring in Wood Tissue: Phytopath. 12: 369–374; August, 1922.
[19] Colley, R. H., The Relation Between Color and Toughness Strength in Commercial White Ash: Prog. Rept. pp. 1–5; 1924.
[20] Luxford, R. F., Effect of Decay on Strength of Commercial White Ash: Office report, Forest Products Laboratory; 1922.

FIGURE 16.—Honeycomb in the "mineral streak" areas of kiln-dried maple. Note that no checking appears in the areas beyond the discolored portions, and that in the transverse section the checks are placed radially and are confined to the spring wood of the annual ring. The transverse section at left shows typical zone line and incipient discoloration characteristic of early stages of decay.

wood. The discoloration is apparently an early stage of some common heart rot of maple.

The following key is submitted as an aid in roughly determining the causes of given discolorations in wood other than the brownish discolorations of wood and those produced by the early stages of wood-rot organisms:

KEY FOR THE IDENTIFICATION, BY COLOR, OF WOOD STAINS CAUSED BY FUNGI

A. Stains found in sapwood ..... A–1; A–2; A–3; A–4; or A–5.
A–1. Blue to bluish black ..... A–1–a or A–1–b.
A–2. Brown to olivaceous black ..... A–2–a; A–2–b; A–2–c; A–2–d; A–2–e.
A–3. Green, or shades of green ..... A–3–a or A–3–b.
A–4. Rer, or shades of red ..... A–4–a or A–4–b.
A–5. Yellow, or shades of yellow ..... A–5–a.

A–1–a. Bluish gray or bluish black in softwoods and hardwoods (*Ceratostomella* spp.) ..... BLUE STAIN.
A–1–b. Bluish black to grayish black (*Graphium* spp.) ..... BLUE STAIN.

A–2–a. Reddish brown to dark brown, in softwoods, sometimes associated with blue stain in sapwood (*Sclerotiopsis* spp.)[21] ..... BROWN SAP STAIN.
A–2–b. Grayish-black streaks or patches, in ash, cottonwood, aspen, birch, maple, pine, and hemlock (*Torula ligniperda*) ..... BLACK STREAK.
A–2–c. Brownish black to black (*Hormiscium gelatinosum*) ..... BLACK STAIN.
A–2–d. Olivaceous black, principally in hardwoods (*Lasiosphaeria pezizula*) ..... GRAY-OLIVE STAIN.
A–2–e. Intense black in irregular patches, in pines and hardwoods (*Homodendron* spp.) ..... BLACK STAIN.

A–3–a. Bright verdigris green, principally in hardwoods (*Chlorosplenium aeruginosum*) ..... GREEN STAIN.
A–3–b. Bright verdigris green, in softwoods (*Chlorosplenium aeruginascens*)[21] ..... GREEN STAIN.

A–4–a. Orange to red, in scattered spots, on softwoods (*Penicillium piniphilum*) ..... ORANGE-RED STAIN.
A–4–b. Pink, red to violet blotches, in pines (*Fusarium roseum*[21] group) ..... PINK STAIN.

A–5–a. Bright yellow color, in streaks or patches, in hardwoods (*Penicillium divaricatum*[21] group) ..... YELLOW STAIN.

B. Stains found in heartwood ..... B–1; B–2; B–3; or B–4.
B–1. Brown to black ..... B–1–a; B–1–b; or B–1–c.
B–2. Green ..... B–2–a.
B–3. Red, or shades of red ..... B–3–a.
B–4. Yellow ..... B–4–a.

B–1–a. Reddish brown to dark brown, in softwoods, often associated with blue stain in sapwood (*Sclerotiopsis* spp.) ..... BROWN SAP STAIN
B–1–b. Grayish black streaks or patches, in ash, cottonwood, aspen, birch, maple, pine, and hemlock (*Torula ligniperda*) ..... BLACK STREAK
B–1–c. Olivaceous black, in hardwoods (*Lasiosphaeria pezizula*) ..... GRAY-OLIVE STAIN

B–2–a. Bright verdigris green, in hardwoods (*Chlorosplenium aeruginascens*[21]) ..... GREEN STAIN

B–3–a. Pink to carmine red, in box elder (*Fusarium negundi*) ..... RED STAIN

B–4–a. Light lemon yellow, in streaks or patches, in oak, birch, chestnut, and hickory (*Penicillium divaricatum*[21] *group*) ..... YELLOW STAIN

[21] Fungi-producing coloring matter which stains the wood cell walls. The other fungi discolor the wood mainly through the presence in the wood tissues of colored hyphæ. Certain blue-stain fungi have the ability to stain the cell walls to a certain extent.

INTERIOR BLUE STAIN

Casehardening, or a "setting" of the outer layers of wood during seasoning, has often been confused with unequal drying as a direct factor in producing certain stain and decay defects in lumber, developing in the central core of the wood. Both interior dote (figs. 17, A and 17, B) and interior stain (figs. 18 and 19) may be found in casehardened lumber.[22] In rare cases where casehardening is present in rapidly and unevenly seasoned stock of larger dimensions the rapid removal of moisture from the surface layers of wood favors the development of fungi in the interior areas by breaking the water column leading from the moisture-laden interior to the drier surface. Following the rapid drying and setting of the outer layers of wood the diffusion of moisture from the center outward is retarded. A somewhat different but perhaps more common condition in seasoned stock—but giving similar results—is to be found in the unequal moisture distribution in a piece of wood which leaves the outer layers of wood too dry for fungous development and which contains favorable moisture conditions in the central areas. The outer layer in wood showing interior development of fungi becomes too dry to favor fungous development, but in the central moist area the conditions remain favorable long enough for the blue-stain fungus to thoroughly stain the central area (figs. 18 and 19) or for the white-rot fungus in elm to completely rot the central portion (fig. 17). In samples showing interior stain the surfaces of the board appear bright except occasionally where crossers come in contact with the stock. Upon resawing such stock, however, the entire central areas are found to be heavily blued. Western yellow pine plank stock, when air-seasoned, appears to be particularly susceptible to this type of defect. It is occasionally found in 8/4-inch and thicker sap gum stock which has been improperly steam treated.

The question is frequently asked, "How does the fungus enter the plank?" Studies so far conducted have shown that the stain organisms may enter by way of the moist areas where the crossers or stickers rest upon the boards. Here the blue stain appears upon the surfaces and extends through the wood to the opposite face. Where the entire piece shows no signs of blue stain upon the surface another answer must be sought. Sections for microscopical examination, when cut from an area including both stained and unstained wood, very often show the unstained cells containing several small colorless threads of a fungus. The adjacent heavily blued cells show numerous brownish-colored threads of a larger diameter than the colorless ones. Both types of threads are recognized as those belonging to the blue-stain organism. Apparently the unstained outer areas when in the green condition favored the entrance of the fungus, but upon rapid drying the fungus growth was arrested. During the early development of certain blue-stain fungi the hyphæ remain colorless, and as they age they become brownish in color, thus imparting a bluish color to the wood. The young colorless hyphæ succeeded in reaching the more moist central region and there were able to continue their development. The rapid removal of moisture from the outer layers of wood, however, had prevented the further develop-

[22] See footnote 7.

ment of threads to the point where they turned brown and discolored the wood. Hence the outer layers of wood remained clear of stain.

The control of this defect is difficult, and only in the case of interior dote in elm has any control method been tested. For the prevention of interior dote in 6/4 and 8/4 inch elm a steaming treatment has been reported effective.[23] It is believed that effective steaming methods for the control of interior stain are practicable and that avoidance of " setting " in the stock may also prove of value.

The conditions for the rapid development of staining fungi are an abundant food supply, a comparatively high moisture content of the wood, and warm weather. Staining is always severe during rainy periods in the warmer seasons of the year, when the air is humid and the wood dries correspondingly slowly. Very heavy staining may occur in such circumstances, more particularly when lumber fresh from the saw is bulk-piled, or when green stock is improperly stored or shipped in closed cars or in the holds of vessels.

It has been observed that the mold fungi grow best on substances which contain some acid, for which reason normal acid sap and the " sour " sap containing even more acid make a very favorable medium for the rapid development of the stain organisms.[24] This fact is believed to explain in part why alkaline dips which neutralize the acidity of the sap are effective in the prevention of stain.

Some of the staining fungi appear to prefer certain species of wood. The exact nature of this affinity, whereby some species of wood seem to " blue " more readily than others, has not been determined. Perhaps the food or moisture conditions in the sapwood vary sufficiently among species to account for the selective action. Curiously enough, the heartwood seems to be unfavorable soil for the development of molds, and the blued areas frequently end where the heartwood begins. This peculiarity of behavior has often been discussed, and general opinion now inclines toward the theory that a favorable field for the development of the stain fungi is found in freshly killed sapwood which has lost some moisture and gained a little air. In a few rare cases blue-stain organisms have been found in the heartwood of certain woods. These woods are usually of the type that show little difference between sapwood and heartwood and in which the heartwood shows a fairly high moisture content.

MOISTURE CONTENT IMPORTANT

The amount of moisture in the wood thus appears to be a determining factor. Apparently the heartwood in many cases is not moist enough and the sapwood of the living tree perhaps too moist to favor the growth of blue-stain fungi. Since it is not feasible to keep lumber wet after manufacture, it is obvious that in the air-seasoning, storing, and shipping of wood products the main effort in the prevention of stain lies in the opposite direction—rapid drying.

Investigations here and abroad have demonstrated that the species of fungi causing blue stain react quite definitely to different moisture contents in wood. The writer has conducted tests by growing a particular fungus on several pieces of fresh sapwood, the pieces containing known amounts of water in a graduated series. It was

[23] Loughborough, W. C., and Hubert, E. E., Problems in the Seasoning of Southern Hardwoods: So. Lumberman 117: 170–174; 1924.
[24] Rumbold, C. T., Blue Stain on Lumber: In Science n. s. 34: 94–96; 1911.

FIGURE 174.—Showing the surface of an elm plank which contains "interior dote."

FIGURE 17*B*.—Transverse section of a 3-inch elm plank showing "interior dote." The rot represented by the white areas surrounded by dark lines is seen only in the central part of the plank. The faces of the plank give no indication of the rot within. The scars show evidence of some injury caused by lightning, fire, "bird peck," or other agencies. In this particular sample there is a possibility that the infection entered these wounds in the living tree

noted that the fungi under test showed definite reactions in their growth relations to the amount of moisture in the wood. For instance, a blue-stain fungus developing on pine sapwood exhibited no signs of growth below a moisture content of 20 per cent (oven-dry weight basis), stained the wood heavily at 65 per cent, and at 90 per cent again showed few signs of development. (See Table 2.) Apparently the lower moisture contents gave insufficient water with

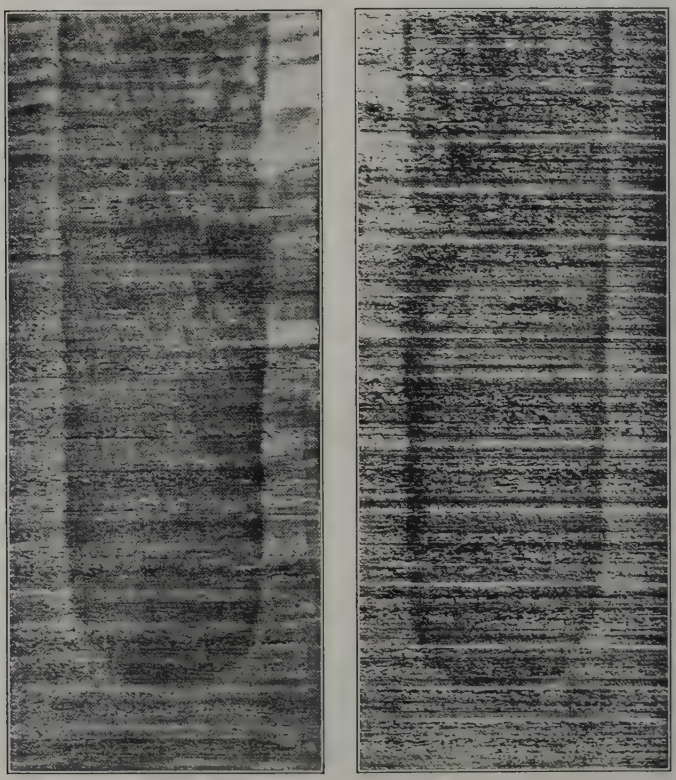

FIGURE 18.—Transverse sections cut from 6/4-inch sap gum boards improperly steamed and then air seasoned for about one year. Note the central dark areas which represent the blue-stain infection. The faces of these boards before resawing were bright and free from defect

a large amount of air, the optimum or middle range furnished the favorable amount of moisture, while at the highest moisture content there was too much moisture and too little air.

From the data thus far accumulated (Table 2) it would seem safe to assume that at and below a moisture content of 20 per cent of the oven-dry weight, there will be no danger of the development of many of the various sap-staining fungi on any wood species, and

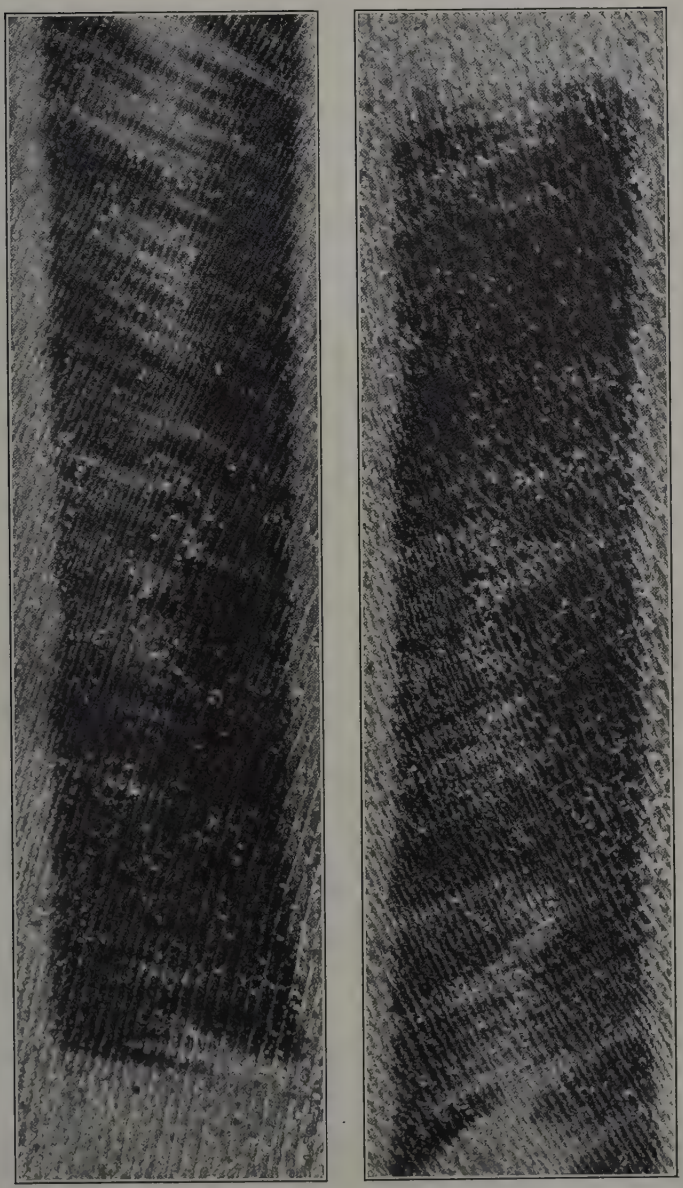

FIGURE 19.—This shows a peculiar type of sap stain, called "interior blue stain," in the center of inch and a half western yellow pine stock. The stock was air seasoned and because of unequal drying the center area remained sufficiently moist to favor the development of blue stain. The grounds for complaints when such material is resawed are obvious

consequently no staining. This means that stock properly dried to a low moisture content and kept dry will be free from stain. Moreover, proper air-seasoning or kiln-drying to a low moisture content insures against subsequent staining during the storage or shipment of the stock, provided the stock is kept dry.

TABLE 2.—*Relation between sap-stain fungi and moisture content of wood (oven-dry basis), including some wood-rot fungi for comparison*

Fungus		Species of sapwood used	Moisture content, per cent			Investigator
Name	Isolated from sapwood of—		Minimum	Optimum	Maximum	
Blue stain (Ceratostomella coerulea).	Scotch pine	Scotch pine	−28	33–74	143	Muench.
Blue stain (C. pilifera)	Western yellow pine (Pondosa).	Trembling aspen	60	70	90	Hubert.
		Loblolly pine	40	70	90	Do.
Blue stain (Ceratostomella sp.).	Loblolly pine	do	25	65	+90	Do.
Do	do	Trembling aspen	−40	70	+90	Do.
Blue stain (C. pilifera)	Western white pine.	Loblolly pine	25	100	+90	Do.
Blue stain (Graphium rigidum).	Red gum	Red gum	35	130	190	Do.
Brown rot (Trametes carnea).	White spruce	Loblolly pine	100	115	130	Do.
Brown rot (Lentinus lepideus).	Jack pine	Trembling aspen	100	115	130	Do.
Brown rots (L. sepiaria, L. trabea, T. serialis, F. roseus, L. lepideus, Trametes carnea).	Cotton mill lumber.	Loblolly pine (sp. gr., 0.44).	−25	49–72	150	Snell.
		Sitka spruce (sp. gr., 0.35).	−25	43–133	203	Do.
		Southern yellow pine (sp. gr., 0.44).	------	110	160	Do.
		Sitka spruce (sp. gr., 0.34).	------	150	200	Do.
		Douglas fir (sp. gr., 0.57).	------	80	125	Do.
Blue stain (Ceratostomella coerulea).	Pine	Pine	22	41–119	+155	Lagerberg, Lundberg, and Melin.

Heat treatments remove the moisture necessary to the growth of the mold plants, and if sufficiently high temperatures are used the fungi or spores present on the wood are killed outright. Chemical dips, such as solutions of soda, bring about changes in the sap which either make it an unfavorable medium for the development of molds or are poisonous to them. Poisonous chemicals check the growth of the sap-stain fungi or kill them. Rapid removal of the moisture from the surfaces of boards by means of the best air-seasoning methods leaves a dry surface condition unfavorable both to the germination of the spores and to the further development of the plants.

THE EFFECT OF SAP STAINS ON WOOD PROPERTIES

STRENGTH PROPERTIES

Molding and staining do not greatly affect the strength properties of wood. *Blue stain is not an early stage of decay.* However, the value of the product is often lowered for use where discolorations are objectionable, or where wood is to receive a "natural" finish. On the other hand, there is no reason for condemning blued stock without a hearing if it is free of decay and is to be covered, stained.

or painted, and if conditions of exposure permit the use of sapwood. (See fig. 20.)

Considerable work has been done to determine the effect of the blue-stain fungi upon the mechanical properties of the wood they discolor. A variety of results were secured by the various workers. Rudeloff [25] found that the compressive strength of wood infected with a blue-stain organism did not differ from unstained wood, but it appears he took no account of the variation in moisture content of the test pieces, and the results are therefore not as reliable as in tests where this factor is considered. Von Schrenk [26] gives a series of tests made with stained and unstained pieces stating that for all practical purposes the stained wood is as strong as the unstained. He further notes that the higher results secured for the stained wood in tests for compression parallel and perpendicular to the grain are probably due to the difference in moisture content between the stained and unstained pieces. He observed a greater resistance to splitting

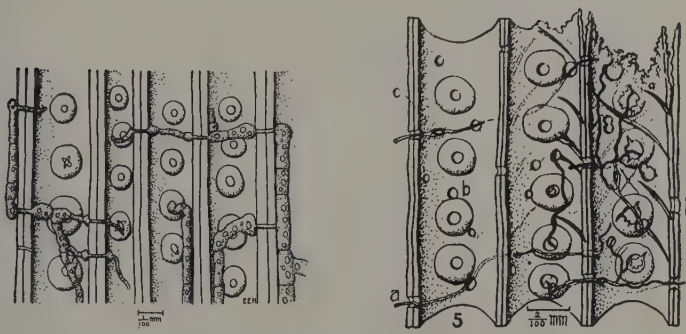

FIGURE 20.—*A*, Threads of a blue-stain fungus in the wood cells of scrub pine. Note the penetration of the walls but no evidence of marked decomposition. Most of the sap-stain fungi do not bore through the walls as this one does. Enlarged about five hundred times. *B*, The threads (*a*, *c*) of a wood-rotting fungus, *Lentinus lepideus*, in jack pine, *Pinus banksiana*. Note the numerous penetrations of the cell walls by the threads through large bore holes. The breaking down of the cell is plainly shown in the upper right-hand corner. Enlarged about five hundred times

along a tangential plane (flat grain) in the blued wood than in the unaffected wood. Münch,[27] testing pine wood infected for six months with the blue-stain fungus, *C. pini* Münch, found the specific gravity less than normal and the resistance to compression slightly weakened. These effects he attributes to the presence of other fungi in the test pieces. Weiss and Barnum,[28] testing stained and unstained pieces of longleaf (*P. palustris*) and shortleaf pine (*P. echinata*), conclude that for all practical purposes the blued wood is as strong as the unstained wood.

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[25] Rudeloff, M., Untersuchungen uber den Einfluss des Blauwerdens auf die Festigkeit von Kiefernholz. Theil I–II. Mitt. K. Tech. Versuchsanst. 15 (1897); 1–46, 55 figs., 17 (1899); 209–239, 9 figs., 1899.

[26] Von Schrenk, H., The Blueing and the Red Rot of the Western Yellow Pine, with Special Reference to the Black Hills Forest Reserve: U. S. Dept. of Agri. B. P. I. Bul 36, 40 pp., 14 pl. (4 col.); 1903.

[27] Münch, E., Die Blaufaule des Nadelholzes: Naturwiss. Zeitschr. Forst—u. Landw. 5: 531–573, 1907; 6: 32–47, 297–323, illus., 1908.

[28] Weiss, H. F., and Barnum, C. T., The Prevention of Sap Stain in Lumber: U. S. Dept. of Agri. For. Service Cir. 192; 1–19; 1911.

The heavily sap-stained shortleaf pine was practically as high as the unstained in bending strength and in stiffness but was slightly lower in toughness and in surface hardness. The longleaf pine was only slightly sap stained, and the tests indicate that the stain had no effect on bending strength, stiffness, or toughness, and little or no effect on hardness. The St. Louis tests [29] on stained and unstained western yellow pine (*P. ponderosa*) give higher results for the stained wood in compression parallel to grain and in static bending than the unstained wood. Weiss and Barnum [30] state this result is probably due to the fact that the stained wood was drier than the normal wood with which it was compared.

A review of the strength tests which have been made indicate a slight weakening effect due to the blue stain. For all practical purposes involving the use of structural timber where large factors of safety are employed and where slight weakening would be of no consequence, the stained wood is apparently as strong as the unstained. The slight weakening, however, such as the lowering of toughness and hardness, might seriously affect the usefulness of sap-stained stock for purposes in which these properties are particularly important.

RESISTANCE TO THE PENETRATION OF PRESERVATIVES

The common statement, often heard, that the presence of sap stain or blue stain in the stock undergoing treatment materially retards the penetration of creosotes and other preservatives into wood seems to have no foundation in fact. Experimental work on a scale large enough to be conclusive has not been done on this project. There is much observational evidence that the high moisture content of the sapwood plays an important part in preventing the penetration of preservatives. Some claim that a hardening of the outer layers of sapwood due to rapid drying is responsible. Again it may be the thin inner layer of bark cells left on the surface of the sapwood after the removal of the bark that retards the penetration of preservatives. In certain species of wood used for poles and posts a perforator is employed to open up the wood before treatment.

Preliminary tests on Pondosa pine and southern yellow pine sapwood using a 5 per cent zinc chloride solution indicate that when clear and blued pieces are both brought to the oven-dry condition and then treated the blued pieces show a much deeper penetration than the clear pieces.

It is said that in Germany and other European countries railroad ties and other wood products showing heavy sap stain are culled from the loads prepared for preservative treatments on account of the resistance offered to the penetration of the chemicals. The blued stock is usually used, however, in an untreated condition. Such statements are difficult to substantiate, and when sifted down it may be found that blued wood is as easily treated as clear wood when good treating conditions are used.

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[29] Von Schrenk, H., The Blueing and Red Rot of the Western Yellow Pine. U. S. Dept. of Agri. B. P. I. Bul. 36. 40 pp., 14 pls. (4 col.) ; 1903.

[30] Weiss, H. F., and Barnum, C. T., The Prevention of Sap Stain in Lumber : U. S. Dept. of Agri. For. Service Cir. 192 : 1–19 ; 1911.

BLEACHING OF BLUED WOOD

Attempts are often made to bleach out the blue-gray color in heavily blued wood products. Several bleaching methods have been suggested for this purpose, but so far none have been successful in producing anything but a superficial bleaching. In preliminary tests made with a solution of calcium hypochlorite on pieces of blued pine wood the blue color was bleached out to a depth of one-sixteenth to one-eighth inch. During the bleaching, however, the outer layers of cells become considerably altered and show signs of brittleness. The commercial bleaching of blued wood has not become a successful practice with the one exception of the bleaching of blued fibers in wood pulp for paper making. Where large amounts of blued wood are used in the making of wood pulp, more bleaching liquid is re-

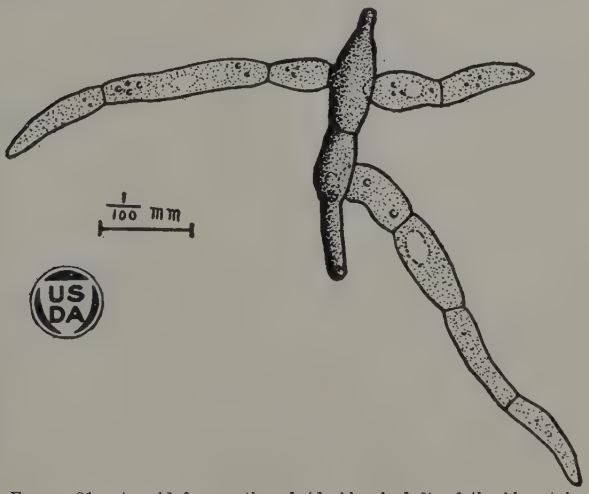

FIGURE 21.—An old fungus thread (darkly shaded) of the blue-stain fungus which has revived and produced three new growing branches. These threads in the wood of eastern white pine were air dry and dormant for some time, but revived when sufficient moisture was applied. Enlarged about eight hundred times.

quired than for wood pulp containing no blued stock. Pulp prepared experimentally from spruce chips was found to require an average of 10.6 per cent bleach powder. That made from selected sound (unblued) chips required only 8.6 per cent, while that made from badly stained chips required 15.7 per cent, based on the air-dry pulp weight.[31]

LONGEVITY OF BLUE-STAIN FUNGI IN WOOD AND THE EFFECT OF HEAT

The blue-stain threads, dormant for a considerable time in wood stored in the dry atmosphere of a room, are capable of reviving and sending forth new threads on the return of favorable growth conditions. (Fig. 21.) In one case the blue-strain fungus remained

[31] Sutermeister, E., The Use of Rotten and Stained Wood for Making Sulphite Pulp: Pulp and Paper Magazine, Canada, 20: 513–514; 1922.

dormant for a period of seven years in the sap zone of a piece of structural timber, and when cultured at the end of this period it grew vigorously on the artificial food. The above fact has an important bearing on the piling of lumber for air-seasoning or for storage and on the shipment of lumber and other wood products in closed box cars or in the holds of vessels. In stock which has not been sterilized by heat or other means it is important to reduce the moisture content below 20 per cent as soon as possible. It is equally important to keep the material dry once it has been properly seasoned, for the fungus may revive and continue to spread as long as sufficient moisture is present for its growth.

The results of experiments on the effect of heat upon sap-stain fungi within the wood have a direct application in the kiln-drying and steaming of lumber. The killing of sap-stain and decay organisms present in the green wood may prevent considerable spread and development of these organisms during air-seasoning, storage, or in transit.

The tests so far conducted[32] show that a temperature of 140° F. maintained for three hours at saturated atmosphere (relative humidity, 100 per cent) kills the blue-stain fungus in Eastern white pine (*P. strobus*) and in Northern white cedar (*Thuja occidentalis*) in 1 and 2 inch stock containing blued sapwood. The fungi remained alive, however, in the central portions of the 4-inch stock. After treatment of the 1, 2, and 4 inch test pieces for six hours under the above conditions no revival of the fungi was observed. The tests also indicated that the sap-stain organisms and the molds in general were more resistant to heat than were many of the wood-destroying fungi. In some cases mold growth is found developing on boards in the dry kiln and thus obstructing the circulation. In general practice it has been found[33] that a preliminary steaming of the stock at 170 to 180° F. for a period not exceeding an hour stopped the surface growth of mold. This treatment heats the surface of the stock sufficiently to kill the mold, and at the same time too-rapid drying is prevented by the saturated air.

RELATION OF BARK BEETLES TO SAP STAIN

Several references may be found indicating the possible relation between the bark beetles and other insects inhabiting standing and felled trees and the sap stain that soon appears following the entrance of these insects. Observational data taken in the field would indicate that bark beetles are carriers of the sap-stain spores and thus serve to introduce these fungi into the moist sapwood. Areas of discolored sapwood are commonly found in close association with the areas under the bark where bark beetles have been active. Similar areas of both blue stain and brown sap stain have repeatedly been observed spreading from the small shot-hole borings made in sapwood by the ambrosia beetles. This is a very common observation in logs stored in decks for periods of time.

The investigations on this subject carried out by the Bureau of Entomology and other Federal bureaus have not yet been published,

[32] Hubert, E. E., Effect of Kiln-Drying, Steaming, and Air-Seasoning on Certain Fungi in Wood; U. S. Dept. of Agri. Bul. 1262: 1–20; 1924.
[33] Forest Products Laboratory Technical Note No. 136.

and detailed information on this interesting point will no doubt appear in time.

Some preliminary tests have been conducted by the writer during 1928. Adults of the bark beetle, *Dendroctonus monticolae*, were captured just prior to their entrance into the bark of the host tree. These beetles were placed, one to a tube, in culture tubes containing malt agar, the tubes and the agar having been previously sterilized. The tubes were set aside for incubation over a period of two to three months, at the end of which time they were examined. It was found that about 75 per cent of the tubes showed fungous growths which were brown to black in color, indicating the presence of dark-colored fungi. The isolation and identification of these fungi, which are numerous in these cultures are in progress in order to determine whether they are sap-stain organisms. The cultural characteristics of several of the organisms resemble closely a blue-stain fungus found in lodgepole pine.

The tests indicate that bark beetles carry spores or fragments of fungous threads attached to their bodies and that these are viable and capable of producing new growths of the organisms they represent.

LOSS DUE TO SAP STAINS

LOSSES IN LOG HANDLING AND STORAGE

The principal losses in stored and improperly handled logs are caused by fungi and insects and by the damage due to checking. A great part of these losses occur in the more valuable hardwood species selected for particular utilization. (Figs. 22 and 23.) Due to seasonal logging and other causes, much of this raw material is accumulated and stored in quantities in order to insure an adequate supply. (Fig. 23.)

This storage of logs is practiced in many of the industries, and the piles may be erected in the woods, at shipping points, at the mill, or at the manufacturing plant. Very often the storage of logs in the woods, at shipping points, or along railroad spurs or main lines is carried on in a haphazard fashion, and the logs are bulked without skids on swampy or undrained ground. Here they are left for a considerable time before they are finally loaded and shipped to their destination. During this storage period stain and decay organisms enter the logs, heart rots may continue to develop (figs. 24 and 25), end checks make their appearance, and insects begin and continue their destructive activities. The data so far accumulated indicate that the loss due to decay in stored logs represents from 3 to as high as 50 per cent of the merchantable volume. We will assume that the lowest figure, or 3 per cent, is lost through decay in storage. This would give an annual loss of 310,000,000 cubic feet on the basis of the total production (1922 basis) of the various groups of forest products taken from industries which usually store quantities of logs for considerable lengths of time. The equivalent in lumber taken from these logs equals more than 1,000,000,000 board feet having an approximate money value of $42,250,000. This is the Nation's annual bill for waste in log storage and handling due to decay alone. The additional losses due to sap stain, end checks, and insects would

perhaps double the above estimate. Such waste and degrade, if prevented, would mean better stock for the purchaser and bigger profits for the operator. The salvaging of this material would ultimately mean a direct saving of stumpage. It is quite possible that a concern planning on a 10-year supply of logs from its timberlands under the wasteful method would be able to extend this to a 12 or 14 year cut under the less wasteful one. The amount of stumpage saved each year by this means would soon show an appreciable reduction of the annual drain on our forest resources.

Logs and trees left in the woods following logging, insect-control work, and similar activities, and following fire and windfall damage, deteriorate rapidly. The data collected by Boyce [34] on western yellow

FIGURE 22.—Red gum logs heavily sap stained during storage in the mill yard. Considerable sap rot has already developed in these logs and many of the boards cut from them will contain some of the infection

pine insect-control projects show that the felled and barked trees lying on or near the ground were completely sap stained by the end of the first season of exposure. Rapid decay of the sapwood, with a slower rate of decay for the heartwood, takes place the first season, and by the end of the second season the volume of the merchantable wood in the felled trees had been so greatly reduced by decay that the salvaging of the logs had become uneconomical.

It is unquestionably true that in better methods of handling and storing logs is to be found the solution to this particular waste prob-

[34] Boyce, J. S., Deterioration of Felled Western Yellow Pine on Insect-Control Projects: U. S Dept. of Agri. Bul. 1140: 1–7; 1923.

lem. But, unfortunately, this is only half the story, for the sap stains and sap rots which enter the freshly cut or the stored log often continue their development in the boards placed in the piles for air-seasoning. This accounts for much of the heavy bluing and rotting of air-seasoned sap gum and for the well-known "interior dote" of elm and other hardwoods. Furthermore, small checks starting in the log during storage become closed when the logs are soaked or kept in the pond and may enlarge during the seasoning of the lumber. It also often happens that boards cut from infested logs contain insects or insect larvæ which may seriously damage the stock unless they are killed by heat or chemical treatment. To complete the story, then, we must add to the log storage the losses due to the deterioration of lumber cut from insect or fungous-infected logs. The

FIGURE 23.—The yard of a large hardwood plant showing long piles of stored hardwood logs, track facilities, and steam loader. Many of these logs when sawed showed from 1 to 3 feet of the ends badly decayed and in some piles the loss due to decay represented 25 per cent of the log volume

prevention of losses in this type of lumber is essentially a seasoning problem. However, these seasoning losses and the losses occurring in log handling and storage can be greatly reduced by improved practices.

LOSSES IN AIR-SEASONING, STORAGE, AND TRANSIT

It is often difficult to understand just how degrade due to sap stain constitutes a loss, and many millmen and manufacturers will say that there is no loss in blued stock because it is eventually sold as lower-grade material. But right here is where the loss occurs, for sap stain develops in otherwise high-grade stock, and the reduction in quality represents a loss in value which is chargeable directly to sap stain. It is not a total loss comparable to a loss by fire; it is a depreciation loss, for blued stock never entirely loses its usefulness

unless decay has developed.[35] It is found that the influence of this loss is far-reaching and has a definite bearing on the overcut of the standing timber in regions where the demand for high-grade material results in excessive cutting and therefore in the accumulation of much low-grade sap-stained stock.

The first loss due to blue stain is in the reduction in grade as the board sawed from a blued log passes over the grading chains. Whether the stock is subsequently kiln-dried or air-seasoned, blue stain at this stage may affect the grade appreciably. Very often blue stain develops in the log and is carried over in the board, acting as a source of infection to the neighboring unstained boards in the same pile.

The next lowering of grade takes place when blue stain develops in the sap boards piled in the yard for air-seasoning. Considerable loss at this stage is found in lumber sold in the rough, unplaned.

Where the blue stain is superficial in lumber which is planed, very often the planing removes the darker stain and mold growth and the product suffers little, but in deeply stained stock the surfacing process does not remove the blemish. Following this, if the stock is stored improperly or shipped under unfavorable conditions, blue stain may again develop and take its toll through degrade. This loss in shipment may occur in rough stock as well as planed stock.

A fourth form of loss occurs in the degrade of the finished product. In such industries as the sash, door, and millwork, the lumber purchased is already graded and the blue stain present in such stock has been accounted for and the degrade applied. When this blued wood is used in the finished product of these mills the sap stain is again responsible for a reduction in the selling price of the product. This reduction in price for blued stock averages 25 per cent in a certain sash, door, and millwork association. It is thus seen that the loss due to sap stain may often occur in the various steps of manufacture, in transportation, or in storage. A pine board may be reduced in grade on the sorting chains on account of stain, it may then go to the air-seasoning pile and suffer further loss, or it may be kiln-dried and, due to subsequent improper storage, further staining may lower the grade. Eventually one of these blued boards may again cause loss in the finished product on account of the blemish. Unlike decay, blue stain rarely causes a total loss of the product.

Another source of loss is represented in the use of molded barrel, box, basket, or other stock in containers used for shipping fresh and perishable food products. The presence of the mold spores in large quantities adjacent to perishable food products may easily cause rapid decay or contamination of the food products and thus result in serious losses. An instance may be cited where moldy basswood box boards were used in the manufacture of containers for shipping butter. The mold, under favorable conditions, contaminated the butter in these boxes and so caused a heavy loss. Fruits and vegetables may become contaminated in a similar manner.

The veneer industry uses the best grade of logs, 16 inches at the small end, and without defects, and this calls for the cutting of the

[35] Hubert, E. E., The Utilization of Blue-Stained Wood: Sash-Door Finish. 4: 17, September, 1922; Hardwood Record, Oct. 25, 1922. Also see Forest Products Laboratory Technical Note No. 184.

finest trees in the virgin stands. In red gum, for example, the heartwood may be used for veneer or for lumber. In either case the demand for the heartwood is often greater than for the sapwood products, and the sap gum stock accumulates. During the short period of air seasoning this accumulated stock deteriorates rapidly through sap stain.

It is unquestionably true in a great many instances that what amounts to an overproduction of the lower grades of lumber and other wood products may be traced to the discoloration of sapwood by fungi. A very large amount of timber must be cut in order to produce a large amount of upper-grade stock free of stain, and this alone results in the accumulation of the less desirable lower-grade stock. Species with a large percentage of sapwood are foremost on this list. At one of the western mills cutting western yellow pine as much as 75 per cent of the air-seasoned selects and shop-grade stock is reduced in grade, due to sap stain developing during the less favorable months. In this way sap stain increases the total of lower-grade stock by reducing the amount of upper-grade material. To the bluing of sapwood, therefore, may be laid indirectly a considerable part of the annual cut, which could otherwise be reserved for future use.

In a study of the sap-stain problem it is found that these losses are not confined to the United States but are world-wide, occurring wherever trees are cut for lumber. For instance, Wilson,[36] writing on the bluing of coniferous timber, estimates that in Germany the value of timber affected by blue stain is diminished from 25 to 50 per cent; in Sweden the depreciation in value of blued timber is 14 per cent; in Great Britain blued wood is priced considerably lower than bright stock, and for many uses blued wood is not accepted at all; and in Russia the damage due to blue stain is considered very serious, principally on account of transportation difficulties which delay the cutting of the logs into timber.

The general attitude of the lumber trade of many foreign countries toward sap-stained material is expressed in the specifications for stock exported from the United States. In this country the most rigid demands for bright sapwood are found in the orders for export stock. In 1922 "bright" sap gum sold for from $2.50 to $5 and on up to $15 per thousand board feet above the price paid for blued stock. Southern yellow pine without sap stain brought from $10 to $27 more per thousand board feet than blued stock. In general, the demand is for bright stock, and better prices are paid for this grade. The fact that decay often develops in blued sapwood has perhaps some bearing on the demand for species which the purchaser by experience finds consistently infected with sap stain and "dote."

SAP-STAIN LOSSES

A survey of the principal wood-producing and wood-using industries of the country was begun in 1921 in an effort to obtain loss figures due to degrade on account of sap stain. A total of eight associations were asked to cooperate.

[36] Wilson, M., The Bluing of Coniferous Timber: Trans. Roy. Scottish Arb. Soc. 36: 82–92; 1922.

Questionnaire reports were received with the assistance of the following: Southern Sash, Door, and Millwork Manufacturers Association; Southern Pine Association; Hardwood Manufacturers Institute; Associated Cooperage Industries; Northern Pine Manufacturers Association; Western Pine Manufacturers Association;

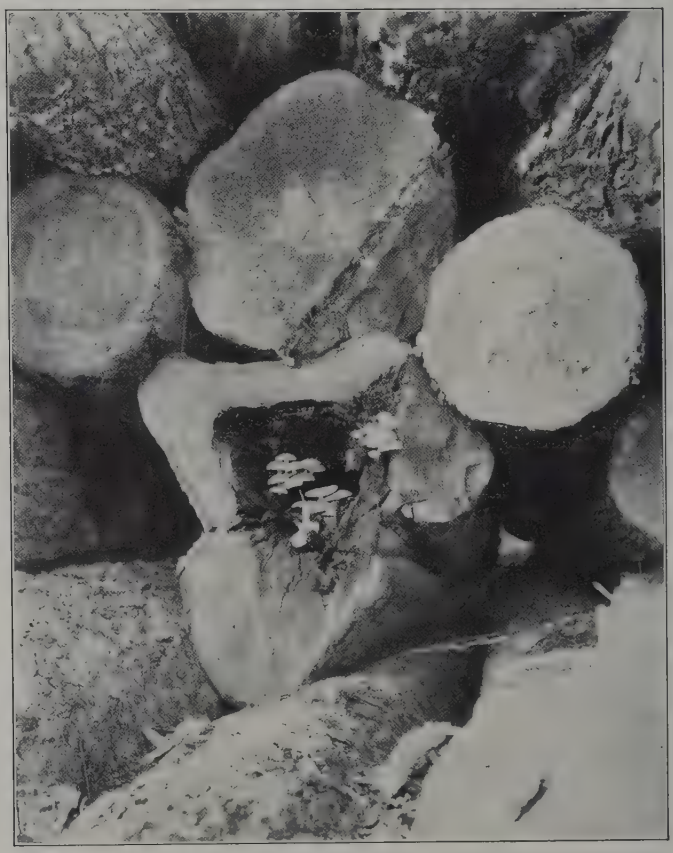

FIGURE 24.—Hardwood logs in storage, showing the fruiting bodies of wood-rotting fungi developing from the decaying heartwood. These signs indicate that the rot in these logs may be extending and gradually reducing the volume of sound wood

California White and Sugar Pine Manufacturers Association; and the Northern Hemlock and Hardwood Manufacturers Association.

As a result of this excellent response, we have to-day more information than has ever before been available on the financial loss due to sap stain. In the reports received many of the mills stated that they suffered considerable loss due to blue stain but are unable

to give actual loss figures. The reports showed that an uncertainty exists in the minds of many lumbermen as to what constitutes loss due to sap stain.

The interpretation of the questionnaire returns is admittedly difficult, due to the fact that it is practically impossible to apply a standard formula in arriving at how much the blue stain is costing the industry. There are many variables to be considered—the different opinions which the millmen hold with respect to blue-stain losses, the variation in species of wood, or in the climatic conditions, or in the type of industry, and in the methods of handling the lumber from log to finished product.

The mills which reported actual loss in their questionnaire returns gave production figures totaling 1,748,000,000 board feet and loss figures totaling $847,600. This would be at the rate of 48.5 cents per thousand board feet. It is obvious that such an estimate can not be accepted as absolutely final, because the questionnaire reports themselves indicated, as has been pointed out above, the difficulties which stood in the way of obtaining accurate figures at the mill. Personal observation and conversation with millmen all over the country have revealed cases where the degrade due to sap stain ran from $10 to $40 per thousand board feet in high-grade stock. Here the loss was recognized because the stock was so valuable that a fairly accurate record was kept of what happened to it, but such records are not kept of lower grade material. It is obvious, also, that the cost of dipping lumber to prevent blue stain is definitely referable to the action of the fungus. In other words, if the lumber were not actually reduced in value by blue stain, no one would go to the trouble or expense of dipping to prevent blue stain. Dipping costs vary tremendously, from 8 cents to as high as 50 cents per thousand board feet. The results of dipping are not always satisfactory; they do not always prevent a further degrade from blue stain and consequent depreciation in market value. When all of the angles of the question presented above have been considered, an estimated loss of 50 cents per thousand board feet of the species susceptible to blue stain appears to be very conservative. It is found that accurate cost accounting would show the loss to be considerably higher.

What does this loss mean to the country as a whole? As near as we can figure it out there is a gross total of approximately 18,000,000,000 board feet of lumber cut from the susceptible species annually.[37] Some of the species within this group are more susceptible than others, but if we apply the estimated-loss figure of 50 cents per thousand board feet to the production total we arrive at an annual loss of $9,000,000. If to this is added the estimates made by the sash and door industries of $1,000,000 and the estimates of other sap-stain losses and losses due to the brown stain in sugar and yellow pine amounting to $500,000, a grand total of $10,500,000 is obtained.

The above estimates do not include the losses due to staining and molding in the vehicle, basket and veneer, box and container, furniture and woodenware industries, nor in the export trade. The loss due to degrade caused by staining and molding of stock in transit is not included. An example of this type of loss (data furnished by

[37] Reynolds, R. V., and Pierson, A. H., Lumber Cut of the United States, 1870–1920: U. S. Dept. of Agri. Bul 1119: 1–62; April, 1923.

N. O. Howard) is found in the results of a survey of 16 vehicle-manufacturing plants showing a loss of $94,400 for 1918 due to bluing and molding of vehicle stock in transit.

PREVENTIVE METHODS

HISTORY OF PREVENTIVE METHODS

Attempts to solve the sap-stain problem in the United States date back to 1888, when lime in various forms was used on the boards and under the lumber piles. These efforts proved ineffective, and in some instances complaints were registered, because it was believed that the lime dulled the planer knives.

Bryant,[38] discussing the early history of sap-stain dipping practices in lumber, states: "On December 15, 1903, George C. Cowles, of Bay Mills, Mich., was granted the first patent on a process to prevent sap stain. (Letters Patent No. 746678.)" The chief feature of this patent was the immersion of the lumber in a 5 per cent solution of bicarbonate of soda ($NaH\ CO_3$). This patent was declared invalid by the Grand Circuit Court for the Western District of Michigan, on July 23, 1908, on the basis that it did not embrace any new patentable ideas. (Lumber Anti-Stain Co. *v.* Geo. Nester, John Nester, et al.)

Since 1903, when the dipping of lumber in alkali solutions to prevent sap stain became common, considerable experimental work has been done by Government bureaus, and by others, in an attempt to find better methods of prevention. The first record of the use of chemical dips, for this purpose is to be found in the experimental work done in 1905–6 by Chapman in North Carolina, and by H. von Schrenk and others in Missouri and Wisconsin. From 1907 to 1909 considerable experimental work was done by the Forest Service and the results published by Weiss and Barnum in Forest Service Circular 192. In 1909–10 Hedgcock carried out a series of experiments, using various solutions on veneer stock. Teesdale in 1912, Knowlton in 1914, Kupfer in 1916, Pettigrew in 1917, and Howard in 1918 carried out various dipping experiments. Howard's studies on the sap stain and decay of vehicle stock were published in 1922 in United States Department of Agriculture Bulletin 1037.

A summary of the various tests made with sap-stain preventives from 1905 to 1922 is given in Table 3. The outstanding, promising chemicals of the entire group of experiments were found to be limited to a very few, such as mercuric chloride, sodium bicarbonate, sodium carbonate, sodium fluoride, and borax. Of these, the first had to be rejected except for special uses, on account of its poisonous and corrosive qualities. Of the remainder, the sodium carbonate-sodium bicarbonate mixture has been used extensively with varying and not entirely satisfactory results. After several years of practical application, even with all these experiments as guides, no entirely satisfactory method of preventing sap stain under all conditions has yet been developed. This coupled with the fact that blue-stain losses are being more keenly felt, has resulted in a decision to attack the problem anew.

[38] Bryant, R. C. Lumber: John Wiley & Sons (Inc.), New York. Pp. 220–21. 1922.

The various means employed in the prevention of sap stain vary greatly and range from end coatings to steam treatments.

END COATINGS

Of the various methods employed in preventing losses during log storage, the following are to be recommended: Coating the ends of

FIGURE 25.—Birch logs stored in the yard of a plant manufacturing wood derivatives. These logs are piled without foundations. The fruiting bodies of the yellow cap fungus, *Pholiota adiposa*, are observed emerging from the heart rotted areas

logs with various mixtures; spraying the entire log with chemicals; storing logs under water; decking and rapid seasoning; and barking followed by rapid seasoning. The best method is to avoid slow handling or long storage, if possible.

TABLE 3.—*Summary of dipping experiments conducted by various investigators in the prevention of sap staining and molding of wood*

Dates, locality, and investigators	Kind of material treated	Solutions tried	Results secured
1	2	3	4
1905; Skyland, N. C.; S. B. Chapman.	Red gum sapwood.	Sulphuric acid, 7%. Salicylic acid, 1%. Mercuric chloride, 0.05%.	No staining on treated boards. Colors the boards red.
1905–1906; Grandin, Mo.; H. von Schrenk, E. A. Bessey, P. Spaulding.	Shortleaf pine sap boards, open pile.	Sodium bicarbonate, 5%. Mercuric chloride, 1/20%.	Sodium bicarbonate more practical. Mercuric chloride effective but poisonous.
1906; Ashland, Wis.; H. von Schrenk, E. A. Bessey.	White pine and Norway pine sap boards, open pile.	Borax, 5%. Sodium bicarbonate, 2.5%. Mercuric chloride, 0.05%.	Borax gave best results, with mercuric chloride second in value.
1907–1909; Bogalusa, La.; C. T. Barnum.	Longleaf pine sap boards, 1 by 6 inches by 5 feet.[1]	Sodium bicarbonate, 10%. Mercuric chloride, 1%. Mercuric chloride, 0.2%. Mercuric chloride, 0.1%. Sodium hydroxide, 5%. Calcium chloride, 5%. Magnesium chloride, 5%. Carbolic acid (phenol), 2%. Carbolic acid (phenol), 5%. Naphthalene. Sodium carbonate, 4%, plus lime, 2%. Borax, 5%.	Successful dips in order: 1. Mercuric chloride, 0.1 and 0.2%. 2. Sodium bicarbonate (yellow color). 3. Borax, sodium bicarbonate, naphthalene, and phenol not successful. 4. Deliquescent salts not successful. 5. Sodium hydroxide or copper sulphate discolor boards. Best results with open piling.
1909–10; Baltimore, Md.; G. G. Hedgcock.[2]	Veneer peach baskets of poplar, sycamore, beech, gum, and maple.	Sodium carbonate, 10%. Sodium bicarbonate, 6.5%. Sodium bicarbonate, 2½%, plus borax 2½%, plus boracic acid 3½%. Sulphur ½%, plus lime ½%. Mercuric chloride 1/10%, plus hydrochloric acid ½%. Potassic alum, 10%. Sodium bicarbonate, 10%. Phenol salicylate, ½%.	In lumber, sodium bicarbonate 5%–8% is most effective. With veneer baskets a 5–5–50 lime-sulphur mixture gave good results, beside bleaching the wood. Mercuric chloride and hydrochloric acid bleaches the wood. Sodium and potassium compounds tend to redden sycamore and gum heartwood. Sodium bicarbonate 5%–10% recommended for baskets, staves, etc. Kiln-drying is effective. Mercuric chloride too poisonous. Good results with potassic alum.
1910; St. Louis, Mo.; C. T. Rumbold.	Pine and red gum.	Sodium carbonate. Sodium bicarbonate.	See list of publications for results.
November, 1912, 1913; Madison, Wis.; C. H. Teesdale.	Shortleaf pine sap boards.	Sodium fluoride, 4%. Brush treated and covered with sawdust for period of 1 month.	Successful against blue stain.
November, 1914; De Ridder, La.; L. N. Knowlton, Long-Bell Lumber Co.	Longleaf pine sap boards, 1 by 6 inches by 10 feet.	Sodium fluoride, 0.42%. Sodium fluoride, 0.98%. Sodium fluoride, 2.93%. Sodium bicarbonate, 2.25% at 160° F.	Best results with 2.93% sodium fluoride. Sodium bicarbonate less successful and gave brownish color to boards. Cost of 3% sodium fluoride solution was 7 cents more per 1,000 feet b. m., than for 2.25% sodium bicarbonate solution.

[1] 50 pounds aqueous solution needed to treat 1,000 board feet. Hand dipping, 2 men can dip 2,000 board feet per hour.

[2] See Experiments in the Prevention of Staining and Molding in Lumber and Other Wood Products, by G. G. Hedgcock.

TABLE 3.—*Summary of dipping experiments conducted by various investigators in the prevention of sap staining and molding of wood*—Continued

Dates, locality, and investigators	Kind of material treated	Solutions tried	Results secured
1	2	3	4
June, 1916; Quincy Lumber Co., Quincy, Calif.; C. A. Kupfer.	6/4 shop and better.	Sodium fluoride, 4%. Sodium silicate, 10° B. Sodium bicarbonate, 15%, 120°–130° F.	Best results with sodium fluoride. Next best sodium bicarbonate, followed closely by sodium silicate.
Mar. 19–23, 1917; Columbia, Miss.[3]	1,500 feet b. m., longleaf, short-leaf, and loblolley pine sapwood.	Calcium silica fluoride, ½%–¾%. Magnesium silica fluoride, ½%–¾%. Ammonium fluoride, 2½%. Sodium fluoride, 2%, plus soda, 2%. Sodium fluoride, 2½%. Mykantin, 1%. Sodium bifluoride, 2½%, 140°–150° F.	Ammonium fluoride most effective in preventing both blue stain and mildew. Sodium fluoride and sodium bifluoride prevent blue stain but not effective against mildew. Soda and sodium fluoride fairly effective against both blemishes. Magnesium and calcium silica fluoride of no practical value. Mykantin effective against blue stain and mildew but discolors boards yellow.
1922; Forest Products Laboratory, Madison, Wis.; N. O. Howard.	Red oak blocks, ¾ by ¾ by 1½ inches.	A list of 20 chemicals. See page 47, United States Department of Agriculture Bulletin 1037.	Borax controlled sap stain but not mold. Creosote plus kerosene and mykantin gave good results. The latter stains the wood yellow. Hygroscopic chemicals added to the preservatives are not effective. Mercuric chloride plus hydrochloric acid prevented mold and stain in red oak spokes.

[3] Third progress report, R. L. Pettigrew, June 18, 1917, Forest Products Laboratory. J. J. White Lumber Co., Columbia, Miss.

Many individual mills throughout the country, unable to avoid storage or slow handling, have tried an assortment of methods without, however, obtaining uniformly satisfactory results. As early as 1907 von Schrenk[39] tried coating the ends of red gum logs with a thin layer of coal-tar creosote and found this treatment fairly successful. Although preventing the stain and rot fungi from entering the ends of the logs, this treatment did not prevent the entrance of these fungi through the broken bark along the sides. The cost of this end coating was 8 cents per thousand board feet. An ideal end coating may have the following specifications: Cheap and does not discolor wood; easy to handle and apply; not easily removed by water; not harmful to the saw; effective in preventing stain, rot, end checks, and to some extent insect damage. With these specifications in mind, preliminary laboratory tests were conducted in 1924 and 1925 by the writer while at the Forest Products Laboratory. Some of these were tests carried out with pieces of wood sealed in glass jars; a few others were experiments in which fresh green branch and trunk sections of box elder (*Acer negundo*) were used.

[39] von Schrenk, H., Sap Rot and Other Diseases of the Red Gum: U. S. Dept. of Agri. B. P. I. Bul. 114: 1–37; 1907.

These tests indicated that cresol mixed with filled hardened gloss oil and applied to the freshly cut log ends would serve to kill the stain and decay organisms present on the freshly cut surface. It also promised to be effective in preventing the entrance of fungi into the log end after the coating was applied. The waterproofing qualities of hardened gloss oil were already well known and could be depended on to reduce end-checking provided the addition of other ingredients such as cresol did not affect this property. The preliminary tests made by end-coating short bolts of freshly cut box elder

FIGURE 26.—A simple and inexpensive wooden dip tank used for experimental purposes at a California mill. A return steam coil at the bottom of the tank serves to heat the solution when necessary. The inside measurements are: Length 11 feet, width 18 inches, and depth 16 inches.

with a mixture of cresol and hardened gloss oil with filler gave very encouraging results. The coated ends developed neither stain nor other discoloring fungi, while the uncoated and control pieces became discolored with moldlike fungi.

In an article by Loughborough and Hubert[40] the problem of end-coating of green logs was discussed and certain end-coating mixtures were recommended for trial. Later, Knauss[41] began testing some of these mixtures in freshly cut logs in the southern hardwood region.

[40] Loughborough, W. C., and Hubert, E. E., Southern Lumberman 117: 170–174; 1924.
[41] Knauss, A. C., Stain Prevention in Gum: Southern Lumberman 120: 42; Aug. 22, 1925.

Following Knauss's work, Teesdale [42] completed the project and published a report. Three mixtures were tested. The first two were suggested by Loughborough and Hubert, while the third was a modification of the second. The following are the formulas, with the proportions given by weight:

No. 1. Cresylic acid, 1 part; kerosene, 10 parts.
No. 2. Cresylic acid, 1 part; hardened gloss oil, 10 parts.
No. 3. Cresylic acid, 1 part; filled hardened gloss oil, 10 parts.

The tests indicated that spray treatments of gum logs with formula No. 1 prevented stain and decay but were not effective in preventing end checks. The third formula, however, gave very encouraging results. The untreated logs used as controls in these experiments showed considerable end-checking, and the blue stain and sap rot extended from a few inches to 2 or more feet into the log from the log ends.

The cresol-hardened gloss oil with filler is made up as follows:

	Parts
Hardened gloss oil	100
Barytes	25
Asbestine	25
Cresol (cresylic acid)	15

The hardened gloss oil (made up of 8 parts quick lime, 100 parts rosin, 57.5 parts of spirit or solvent) can be obtained from a paint manufacturer, and the barytes, asbestine, and cresol added. The mixture should be thoroughly stirred and when not used should be kept sealed to prevent the loss of cresol by evaporation. The hardened gloss oil and filler serve as an effective waterproof coating, while the cresol is intended to prevent the development of stain and decay. The coating is primarily a log coating but may also be used on the ends of green timbers and plank stock during the period of seasoning. It should also prove of value in coating the ends of green ties and poles before they are piled for storage in order to prevent excessive checking and to reduce stain and decay in these products.

The mixture can be applied cold by means of a stiff brush and should be applied forcibly to the moist surfaces, so that it will adhere tightly to the wood as slow drying takes place. If the weather is cold, a slight heating of the mixture will make it easier to apply. The coating should be thick enough so that it will not run before it hardens, and a sufficiently thick layer should be applied to prevent a cracking of the dried mixture and a loss of moisture. The mixture should be applied to the ends and barked sides as soon as practicable after the logs have been cut from the fallen tree. This will necessitate separating the ends of logs, but it is good practice in any event in order to keep blue stain out of the sapwood. The coating prevents the loss of any great amount of water from the log ends and allows a minimum period of time in which stain and decay organisms may become established upon the fresh moist surface.

The cresol-hardened gloss oil with filler costs in the neighborhood of 50 to 60 cents per gallon (1926) and required about 1 gallon of the mixture to end-coat 12 logs averaging 2 feet in diameter.

[42] Teesdale, L. V., The Control of Stain, Decay, and Other Seasoning Defects in Red Gum: U. S. Dept. of Agri. Dept. Circ. 421: 1–18; 1927.

The spraying of logs with various chemical solutions has found favor more particularly in the control of insects which infest logs. The Bureau of Entomology of the United States Department of Agriculture recommends spraying with a variety of chemicals as means of preventing insects from entering green logs.[43]

It is a well-known fact that the storage of logs under water is an effective means of preventing losses due to fungi and insects and of avoiding end checks. However, the logs should be completely covered with water, because partial submersion or an alternate wetting and drying will favor the entrance of fungi and insects and will no doubt produce checks. Cases are on record in which fire-killed timber infested with flathead borers was salvage cut and the logs hurried to the log pond in an effort to drown the grubs. The method proved ineffectual, for the grubs abandoned the water-soaked portions of the logs and continued to form their destructive tunnels in the portions of the logs floating above the water level.

Stains and decay are unable to develop in well-seasoned and well-cared-for logs, since these contain insufficient moisture. Checks may appear as the result of rapid drying, and certain insects may find the conditions favorable. If sufficiently rapid drying takes place to prevent stain and decay, the practice of decking logs on high skidways may prove beneficial although checks and a certain amount of insect damage may follow. In moist and shady forest areas the logs may be decked in the shade and green brush piled over them, thus reducing evaporation and keeping the logs at a high moisture content unfavorable for fungous development. In extreme cases, where it is found practicable, barking and decking the logs at the proper season may prove effective in preventing all but the damage due to checks. All the methods so far presented, except storage under water, may be used at the same time.

In conclusion, it is well to repeat that the best plan is to avoid slow handling or storage if possible. If the log is kept moving from the time it is cut from the tree until it is sawed at the mill there will be a minimum of sap stain and decay, and the damage due to insects and end checks will be greatly reduced.

DIPPING IN CHEMICAL SOLUTIONS

Earlier experiments with sap-stain preventives have already been mentioned, and a summary of the work, as well as conclusions drawn from a large number of field observations, all seem to point to the fact that we have as yet obtained no perfect dip solution. The sodium carbonate-sodium bicarbonate mixture has so far not been excelled for general dipping practice although under severe weather conditions it also fails to prevent the development of fungi causing discoloration of the sapwood. However, many of these failures may be traced to one or a combination of various factors:

1. Use of too low concentrations of the chemical.
2. Use of cold solutions. The solution should be heated, but the temperature used should be not higher than 160° F., so that breaking down of the chemicals may be avoided.

[43] Craighead, F. C. Experiments with Spray Solutions for Preventing Insect Injury to Green Logs: U. S. Dept. of Agri. Bul. 1079: 1–11; August, 1922.

3. Too much dependence upon hydrometer readings when tests for the alkalinity of the solution are required.
4. Delay in getting the green boards into the dip tank. Bulking of green sapwood lumber encourages stain.
5. Delay in moving the dipped stock direct from the dip tank to the air-seasoning piles.
6. Insufficient spacing in the air-seasoning piles resulting in poor air circulation and therefore slow drying of the lumber.
7. Presence of log stain in the lumber before it reaches the dip tank. Surface treatment does not prevent the development of stain in such boards.
8. Careless mixing of solutions. Inaccurate measurements of amounts of chemicals and water.

Neither of the two chemicals mentioned used separately or in a 50–50 mixture is a perfect preventive under severe conditions, such as continuous rainy periods during the warmer months, but either will go far toward keeping the stock clean. In rainy seasons an 8 per cent solution of sodium carbonate is desirable. In drier weather a 4 per cent solution is usually sufficient. A high grade of soda ash should contain about 58½ per cent alkali, and every effort should be made to conform to this standard of purity. When sodium bicarbonate is used, an 11 per cent solution should be employed in wet weather and 5 to 6 per cent in dry weather. This chemical when dry and pure should contain about 37 per cent alkali.

In recent years no conclusive tests have been made in efforts to develop new chemicals for the prevention of sap stains. A preliminary field test made in 1924 showed that a solution made up of 26 pounds of sodium bisulphite and 9 pounds of sodium fluoride in 100 gallons of water was fairly effective in preventing staining and molding of western yellow pine. The solution was used without heating, and produced no discolorations on the dipped boards. The cost of the solution on a 1924 price basis was $1.94 per 100 gallons.

For dipping wood products used in the manufacture of food containers a chemical solution which will eventually evaporate, leaving no trace of the chemicals on the seasoned wood, is desirable. Preliminary laboratory tests conducted in 1923 indicate that the following solutions, which are of the above type, merit trial under mill conditions. The cresol-caustic soda dip, costing (1924) $0.48 per 100 gallons, contains 4 pounds of cresol (cresylic acid, 95 per cent) and one-sixth pound of caustic soda in 100 gallons of water. Another solution contains 4 pounds of betanaphthol, 3 pounds of caustic soda, and 1 pound of naphthalene in 100 gallons of water and costs $1.08 per 100 gallons. A pine-oil emulsion made with crude pine oil, soap, and naphthalene is a promising dip, but for the concentrations tested the cost ($3.85 per 100 gallons) was far above the other two solutions. It has the advantage, however, of not discoloring the boards.

On the basis of the tests made with the cresol-caustic soda and related dips a patent has been issued to E. Bateman and E. E. Hubert covering the use of this type of sap-stain and mold preventive. (Patent No. 1598699, issued September 7, 1926.)

There are other chemical dips which have been employed under semicommercial conditions, the most promising being mercuric chloride (corrosive sublimate) and sodium fluoride. The former gave

excellent experimental results in a 0.1 per cent solution, but on account of its highly poisonous character and its corrosive action upon metals such as iron its general use is not recommended. Sodium fluoride

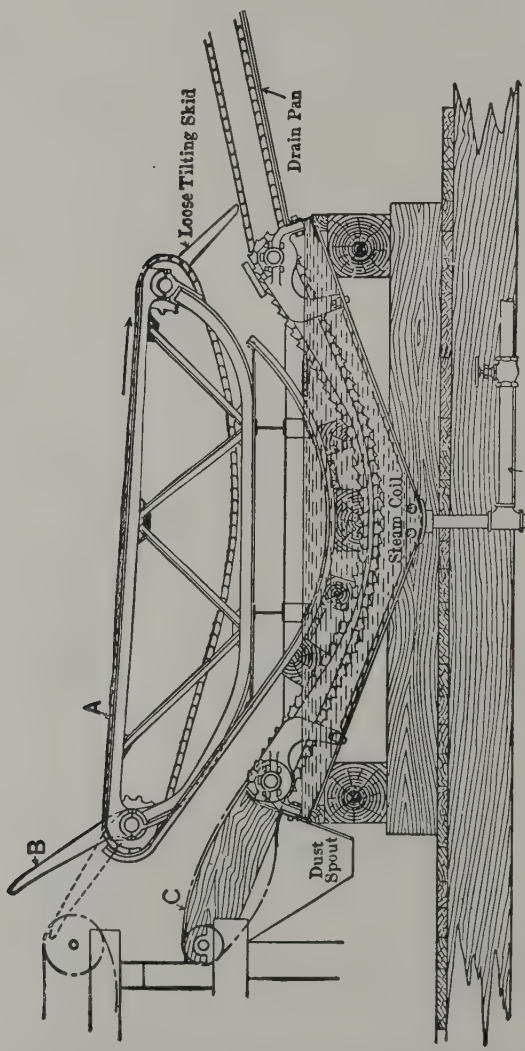

FIGURE 27.—Cross section of one type of metal dipping tank used in the prevention of sap stain. At *A* is shown the by-pass for lumber which is not dipped. The drop of the lumber onto the skid *C* removes much of the adhering sawdust, and thus reduces the amount which accumulates in the bottom of the tank. The drain pan is an economic feature

in a 3 per cent solution can be used successfully against blue stain, but has not given completely satisfactory results under severe conditions, against molds

A 30-day comparative test of three antistain solutions made in June, 1924, by the Virginia & Rainy Lake Co., of Virginia, Minn., is given below:

Pieces of Norway pine	Heated to 140° F.	Period of dip, minutes	Bright	Light mold	Slightly stained	Heavily stained
			Pieces	*Pieces*	*Pieces*	*Pieces*
11 lumber	Not treated					11
50 lath	do		3			47
11 lumber	8 per cent solution sodium bicarbonate	3	3	3	3	2
50 lath	do	3	39		11	
11 lumber	6 per cent solution sodium carbonate and sodium bicarbonate.	3–5	1		5	5
50 lath	do	3–5	14		24	12
11 lumber	0.01 per cent solution mercuric chloride	5	3		1	7
50 lath	do	5	7		23	20

The conditions of the above test were unusually favorable to blue-stain development, as the test material was bulk-piled and then covered with wet blankets. Of the three solutions tested, the sodium bicarbonate solution appeared to give the best results.

COST OF DIPPING

It has been estimated that approximately 50 pounds, or 6 gallons, of solution are needed to dip 1,000 board feet of pine lumber. About 16,000 board feet of lumber can therefore be treated with 100 gallons of solution. This will vary with many factors, such as species of wood, amount of heartwood, presence of "red heart" in the heartwood boards, chemical used, moisture content of the green boards, length of time the boards remain in the solution, etc.

The cost of soda dipping, as well as the method used in computing it, varies considerably within the same general logging region and from mill to mill. The cost per 1,000 board feet at 20 representative pine mills of the South (1925) was found to range from 5 to 35 cents. In a group of 5 mills cutting southern hardwoods the cost ranged from 9 to 50 cents, and at 3 pine mills in the Lake States region the cost ranged from 9 to 75 cents. The high cost of dipping at one mill was traceable to the extra charge for transportation and rehandling due to the fact that the dip tank was not built into the green chain but was placed as a separate unit some distance from the sorting table. The costs will naturally vary with changes in cost of materials and cost of labor. In 1929 the cost for dipping would be somewhat higher than the figures given above.

EQUIPMENT FOR DIPPING

For hand dipping small amounts of lumber, lath, and other products and for experimental purposes a simple wooden tank is found convenient and inexpensive. A small-sized tank of this type is shown in Figure 26. A return-steam coil for heating the solutions and a perforated pipe for use in steaming the lumber can easily be fitted to the bottom of the tank. Many of the tanks or vats at the larger mills are built into the green chains and are constructed mainly

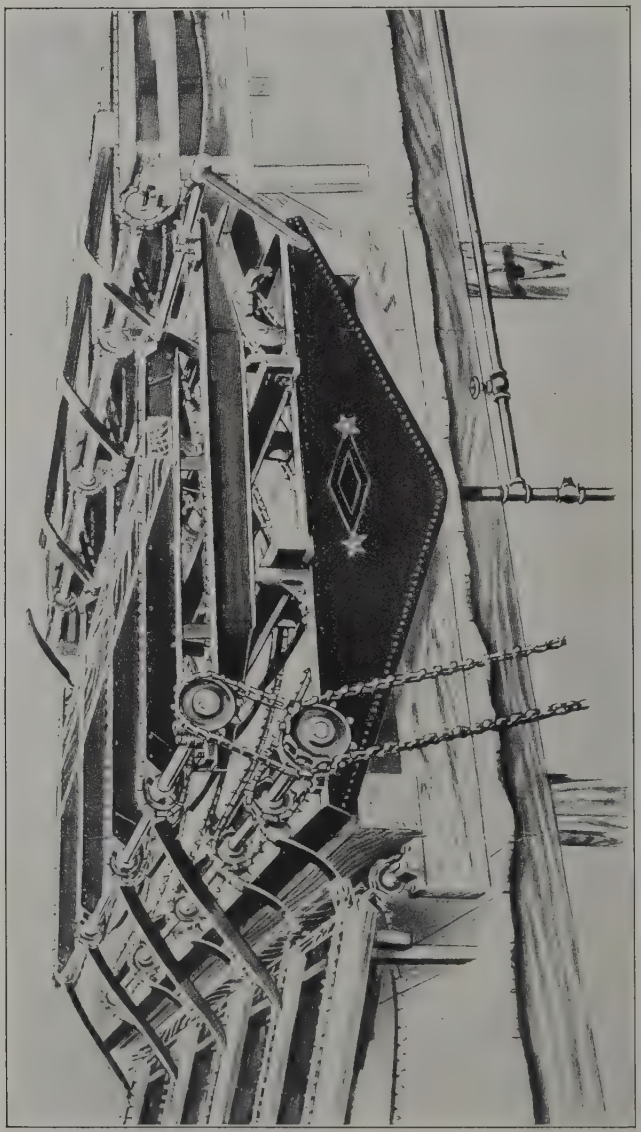

FIGURE 28.—View of the principal parts of a metal dipping tank commonly used in the prevention of sap stain. The by-pass is clearly shown and can be operated by foot power. The drip-pan feature is missing in this installation

of wood. Specially constructed all-steel vats designed with heating coils and with a by-pass to allow certain grades of lumber to pass over the tank (figs. 27 and 28) are in use at many mills where soda dipping is practiced. These tanks are 10 feet wide and are made any length to suit conditions. Timbers as large as 6 by 8 inches can be handled over the chains, which have a speed of about 30 feet per minute. A mixing tank is used in connection with the dipping vat and is placed at some height above the dipping vat. The mixing tank holds about 250 gallons, and in it are mixed the solutions preparatory to filling the dipping vat by gravity flow. Care must be exercised not to use corrosive chemicals in metal tanks.

Thermometers to gauge the temperature of the solution, and hydrometers to test its strength at frequent intervals, are necessary additions to the equipment. The temperature of a soda solution

FIGURE 29.—A view of the type of steam cylinder used in the pressure steaming of certain hardwoods, such as sap gum. The cylinder holds one truck load of open-piled lumber of approximately 3,000 board feet

is an important item and should be checked regularly. Heat coils with perforations or openings permitting the escape of live steam into the solution should not be used. Closed coils with sufficient steam to keep the solution between 140° and 160° F. are required. Heating the solution above 160° F. may cause a change in the chemicals and so weaken the dip solution.

The solution needs to be renewed as soon as it shows signs of weakening. Each board as it goes through the solution uses up a certain amount of the chemical in neutralizing the acid condition of the sapwood. The passage through the solution of several thousand board feet of sapwood lumber soon reduces the alkalinity or strength of the chemical to a point where it is no longer effective as a stain preventive. It is doubtful whether the hydrometer can be depended on to do more than merely register the density of the

soda solutions regardless of their alkalinity. In order, therefore, to test at regular intervals the alkaline strength of the solution, some other method seems desirable. The following equipment was therefore devised for this purpose, and directions for determining the strength of soda solutions are given.

METHOD OF DETERMINING THE STRENGTH OF SODA DIP SOLUTION

APPARATUS AND CHEMICALS

1 Nefis automatic acidity tester.
2 twenty-five cubic centimeter cylinders graduated in one-fifth cubic centimeter.
1 or 2 ordinary white coffee cups.
2 glass stirring rods.
2 liters of one-tenth normal sulphuric acid.
3 ounces of methyl-orange indicator solution in a dropping bottle.

INSTRUCTIONS FOR SETTING UP THE APPARATUS

Be sure that the acid tester is clean and dry before putting it together. Any water in the bottle will change the strength of the acid and cause an error in the readings. When the bottle is dry, pour the normal sulphuric acid into the tester and set it up according to directions. Fill the burette or glass tube on the tester by squeezing the rubber bulb with one hand and closing the little hole in the glass tubing with the thumb of the other hand. Make certain that the burette is full even to the tip. This can be done by wasting a slight amount of the acid. The acid tester is so designed that when the little bulb on the top of the burette is partially filled and the pressure in the bottle is released by removing the thumb from the little tube, the liquid will siphon back, leaving the burette reading exactly zero. It is now ready for use.

INSTRUCTIONS FOR TESTING

Take a sample of the dip solution, fill the graduated cylinder to the 17-cubic centimeter mark and pour this amount into a coffee cup, without draining the cylinder. (Rinse the cylinder with water and hang it up to dry ready for the next test.) Add two or three drops of the methyl-orange indicator to the dip solution in the coffee cup. This will make the solution a yellow or orange color. Now add acid from the burette *slowly* until the solution in the coffee cup turns pink. This occurs when all the alkali has been neutralized. If this is done carefully, the pink will always appear at the same burette reading with the same sample. Read the burette graduation and divide the reading by two. This will give the percentage of bicarbonate present in the dip solution.

EFFECT OF SODA DIP UPON THE STRENGTH OF WOOD

Weiss and Barnum[44] in 1911 tested the effect of soda dip upon shortleaf and longleaf pine boards. The claim had been made that

[44] Weiss, H. F., and Barnum, C. T., The Prevention of Sap Stain in Lumber: U. S. Dept. of Agri. F. S. Circ. 192: 1–19; 1911.

boards dipped in a sodium bicarbonate solution became brash and brittle. The tests made show that the soda-dipped wood is slightly stronger, stiffer, and tougher than untreated wood, but the difference is so small that the normal variations in the wood may account for it. The hardness tests indicated a slight increase in surface hardness of the soda-dipped shortleaf pine and no increase in case of the dipped longleaf pine. The hardness increase in shortleaf pine disappeared after the boards became thoroughly air-dry. As a result of the above tests the conclusion was reached that sodium bicarbonate treatment does not affect the strength properties of the wood.

STEAMING

PRESSURE STEAMING

In certain regions of the South lumber green from the saw is steamed under pressure previous to seasoning in the yard. The equipment used consists of heavy plate metal cylinders equipped with track, trucks, and a close-fitting door. (Fig. 29.) Certain types of these cylinders are known as Kraetzer Preparators, and the product is sometimes termed "Kraetzer-Cured" lumber. It is apparent that these cylinders represent a considerable outlay of capital. Along with the small capacity and large steam consumption this equipment is limited in its use to certain types of mills.[45]

The schedules for steaming sap gum in these cylinders vary considerably. For 4/4 sap gum the time of steaming ranges from 15 to 40 minutes and the gauge pressure from 20 to 30 pounds. For 6/4 stock, 20 to 30 minutes at approximately 30 pounds pressure is used. For 8/4 stock, 45 minutes at 30 pounds pressure is frequently used. Red gum, as well as red oak is treated by this process with the following schedules: 6/4-inch red gum, 40 minutes at 15 pounds pressure; 8/4-inch red gum, 50 minutes at 10 pounds pressure; 6/4-inch red oak, 30 minutes at 25 pounds pressure. In most cases pressure within the cylinders may drop considerably below the listed pressures due to expansion of pipe and cylinder and to condensation of steam.

The mills using this method of seasoning claim that it appreciably shortens the air-seasoning period, prevents stain, mold, and decay, eliminates certain mechanical defects common to air-dried stock, and changes the color of sap gum from white to pink. Care must be taken, however, to avoid severe surface checking. Rapid handling from the cylinder to the pile is essential in preventing sap stain.

In addition to the above advantages, it is of interest to note that high temperatures maintained for sufficient periods of time are effective in killing the fungi and insects present in the green boards. It has been reported that piling the lumber to allow sufficient slope for draining the condensed moisture is beneficial in removing the surface sap, and therefore the board surfaces are less favorable to fungous growth.

Steam boxes of various design are in general use in the cooperage and other industries where the stock is steamed at atmospheric pressure for several hours in order to soften the wood fibers prior to

[45] Murial, C. J.: Steaming Gum Lumber Ahead of Yard Drying: Hardwood Record 53: 22–23; May 10, 1922.

cutting or sawing. (Fig. 30.) In the cooperage industry the stock is steamed for 12 to 24 hours. In some of the veneer plants the short bolts are kept in tanks of water heated to a temperature near the boiling point for several hours. If the products cut from logs or bolts treated in this manner are handled so that rapid drying of the surfaces takes place, reinfection by stain and mold fungi may be avoided.

STEAMING PRELIMINARY TO AIR DRYING [46]

Steaming at high temperature is beneficial for two reasons: First, it sterilizes the wood by killing the rot and stain fungi and also the insects; second, it furnishes heat for rapid surface drying when the

FIGURE 30.—Trucks loaded with hardwood cooperage billets ready for shunting into the steam boxes shown at the rear where the green stock is steamed at atmospheric pressure for 24 hours. A view taken at a cooperage plant in Tennessee

stock is pulled out. But the technique of preliminary steaming must be right; the losses usually charged to the process itself should really be charged to faulty operation.

In the case of sap gum, for instance, if the material is allowed to cool in the preparator or steam box in a saturated atmosphere, the remaining heat is insufficient to dry the surface rapidly upon exposure to the outside air. In reality the surface may be wetter than before steaming and is in fact an ideal condition for the germination and rapid development of fungous spores alighting out of every breeze.

Fungi will develop on green sap gum even after steaming *if it is bulk piled for even a short time*, from which it would seem that

[46] Loughborough, W. C., and Hubert, E. E., Southern Lumberman 117: 170–174. Illus. Dec. 20, 1924. See also U. S. Dept. of Agri. Dept. Cir. 421. 1927.

unless the surface is dried by evaporation as fast as the moisture transfuses through the wood from the inside, the surface is soon put in a condition favorable for fungous infection. In order, then, for a steaming treatment to be beneficial to the seasoning of sap gum, it is necessary to pull the stock out of the steaming chamber hot, avoid bulking, and thereafter keep it drying as fast as weather conditions will permit, taking care to stack it properly and to shelter it with an adequate roof.

STEAMING AS A CURE FOR DOTE IN ELM

Elm, particularly in the heavier dimensions, degrades badly from interior dote. It is reported that considerable elm and a lesser amount of other hardwoods are rejected annually in some of the lumber centers on this account. The prevalence of dote lowers the standard and debars valuable hardwoods from the place they would otherwise occupy in the manufacturing world. Sufficient data have been obtained regarding this harmful defect to warrant efforts to control it by the steaming method. Steaming for two or three hours at 180° F. is a cure for the difficulty, and when once the treatment becomes a general practice the market for elm and other affected hardwoods will be larger. As a matter of fact, all southern hardwoods can be steamed beneficially to hasten drying and to prevent stain and decay.

THEORY OF STEAMING

Steaming seems to boil and wash away certain elements of the sap liquid. It is possible that the elements washed away from the lumber are more or less necessary to fungous development. It is upon this theory that at some mills the sap gum is steamed for 14 hours and longer in a steam box at atmospheric pressure. Experiments made by the Forest Products Laboratory indicate that, however necessary the sap liquid may be to the development of fungi, a steaming treatment of four or five hours is as beneficial from the practical standpoint as the longer periods.

Since saturated steam can give up its heat only by condensing, a pound of water results from every pound of steam required to warm up a load of lumber in a preparator, kiln, or steam box. If the water settles on and soaks into the lumber, the gain in heat content must expend itself in evaporating the moisture deposited on it by the steam, and the lumber is no drier after cooling than it was before steaming. A real gain of heat in a steaming treatment, then, can be effected only by stacking the stock so that the water will run off before it is absorbed. Theoretically, edge-piling would be the ideal arrangement. The proper duration of the treatment from the standpoint of drying results would be the time required to heat the wood and its contained water to the temperature of the surrounding medium. Roughly, the time can be estimated at one hour for each inch in thickness. Some additional time may be allowed to insure sterilization. Most fungi are killed in 4/4 stock when exposed for 40 or 50 minutes to a temperature of 200° F. For 8/4 stock at the same temperature an exposure of 1½ hours was found effective. In the case of insects present in the green lumber, observations indicated that the steaming treatment—4 to 5 hours at 200° F.—was

fatal to them. This is assumed from the data on temperatures fatal to insects in seasoned lumber.[47]

A caution must be voiced here in regard to too-long exposure of certain hardwood to 200° F. in order to avoid weakening of the wood and honeycombing.

Within recent years the Forest Products Laboratory has made a special study of steaming southern hardwoods in a 2-tracked end-piled room 60 feet long. The advantages of this type of steaming treatment became apparent from the start. It was found that 4/4 plain sap gum, when steamed five hours at about 200° F., was dry enough to ship within 7 to 10 days. The stock was practically free of checks. It was straight and flat and exceptionally clear and bright. The end rot so common in sap gum had been arrested before it had time to develop into a source of degrade.

SCHEDULES

The data show conclusively that 4/4 plain sap gum, ash, and black gum can be successfully treated in a steam box. The best results were obtained by opening both doors at the conclusion of the steam treatment. After about two hours the box could then be unloaded comfortably. If the requisite kiln cars and tracking facilities are available at a mill, the lumber should be left on the cars for 10 days or 2 weeks, after which (with summer drying conditions) it is then usually ready to ship.

Different in behavior were plain red gum and oak (4/4 stock), which surface-checked severely when given a similar treatment; that is, 200° F. for five hours and pulled hot. This difficulty was overcome by keeping the doors closed after the steaming treatment until the stock had cooled to about 140° F. Pulling the charge at this temperature almost eliminated the surface checking. The treatment was so effective in killing the fungi and worms and the subsequent drying rate on the yard so satisfactory that no experiments were made with shorter steaming periods.

For quarter-sawed gum and oak, the steaming was not shown by the study to be good practice. Aside from the destruction of fungi and worms, no special advantage was noted The quarter-sawed stock (4/4, 8/4, and 10/4) after being steamed seemed to shrink and collapse worse than unsteamed material. The data, however, are not conclusive on this point. More work will have to be done with quarter-sawed items before definite conclusions can be reached about them.

ADVANTAGE OF THE STEAM-BOX TREATMENT

Large quantities of lumber can probably be steamed cheaply in a steam box. The treatment sterilizes the stock, and the subsequent drying rate on the yard is faster than stock which is air-dried alone. If properly handled, there is little danger of stock ever becoming dozy, and stain is reduced to a minimum. The appearance of the lumber is very pleasing. It is bright and straight, and checks are rare.

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[47] Snyder, T. E., and St. George, R. A. Determination of Temperatures Fatal to the Powder Post Beetle: Journ. Agr. Res. 28: 1033–1038; June, 1924. See also article by Snyder in Journ. of America. For.; December, 1923.

The steaming treatment has been found to be an efficient method of straightening badly warped air-dried sap gum. What this means to the gum industry can hardly be appreciated until one has taken a census of the large amount of warped sapwood lying around almost every hardwood sawmill.

An interesting process reported to be highly successful by one of the mills that were having trouble in keeping blue stain out of the "sap clears" is given below. The green lumber, composed mostly of the higher grades and containing much sapwood, is open-piled on a truck using inch crossers. The truck load is then run into a watertight box, and hot water is used in which to steep the lumber for a period of two to four hours. Steam is introduced into the box to raise the temperature of the water. After treatment the stock is open-piled in the yard, and a shortened drying period with the elimination of stain is claimed for this method.

The following schedules for steaming various woods were prepared and recommended for trial in attempts to prevent sap stain. In arranging the schedules the time-temperature combination necessary for sterilizing to the center of the stock and the kiln-drying temperatures recommended in the Kiln-Drying Handbook, United States Department of Agriculture Bulletin 1136, were carefully considered. For stock which is susceptible to checking the recommendation is made to leave the heated lumber in the steam box for a stipulated period following the shutting off of the steam.

TABLE 5.—*Trial schedules for steam-box treatment (steaming preliminary to air drying)*

Species	Thickness of stock, inches	Steaming at atmospheric pressure, hours	Temperature, °F.	Treatment following steaming
Sap gum	4/4 sap	5	200	Remove from box or open both doors; pile after 24 hours.
Do	6/4, 8/4, 10/4	5–6	200	Do.
Elm	12/4	6	190	Do.
Ash	4/4	5	200	Do.
Black gum	4/4 sap	5	200	Do.
Poplar	4/4 sap	4–5	190	Do.
Soft maple	4/4	5	200	Leave in closed steam box until temperature drops to 100° F.; remove and pile.
Basswood	4/4	4–5	170	Leave in closed steam box until temperature drops to 150° F.; remove and pile.
Douglas fir	8/4	4	160	Leave in closed steam box until temperature drops to 130° F.; remove and pile.
Sitka spruce	4/4	3	145	Leave in closed steam box until temperature drops to 120° F.; remove and pile.
Do	8/4	4	145	Do.
Southern yellow pine.	4/4	4	200	Leave in closed steam box until temperature drops to 180° F.; remove and pile.
Do	8/4	4	180	Leave in closed steam box until temperature drops to 160° F.; remove and pile.
Western yellow pine.	4/4	4	200	Leave in closed steam box until temperature drops to 180° F.; remove and pile.
Eastern white pine.	4/4	4–5	180	Leave in closed steam box until temperature drops to 160° F.; remove and pile.
Western white pine.	4/4	4–5	180	Do.

AIR-SEASONING

BLUE STAIN IN RELATION TO PILING PRACTICES

A goodly share of the annual loss due to the bluing of lumber and other wood products occurs in the mill yard during air-seasoning. Sapwood boards fresh from the saw remain bright only under conditions which favor rapid drying. Slow drying, on days when the atmospheric moisture is high and the weather warm, invariably results in a rapid and intensive development of blue stain and other molds. Under such atmospheric conditions the methods used in handling and piling the stock have a very direct bearing upon the amount of degrade resulting from stain.

Bulk-piling the boards for periods of time longer than 12 hours previous to placing in seasoning piles should be strictly avoided in the interest of early drying. Whether or not sap stain actually appears in the bulked boards within 12 hours, it is quite possible that the stain fungi will have at least begun to grow and that the discoloration following this growth will later appear in the piled lumber. If it can be done economically, the practice of open-piling green boards, with crossers, on trucks at the sorting chain without previous bulking and then shunting the loaded trucks to sidetracks in the yard for air-seasoning recommends itself for trial. At all events, the sooner the green boards are freely exposed to the air for drying the better the results will be in respect to stain prevention.

Since ample air circulation about each board is one of the principal factors in evaporation, it follows that any method of piling that allows greater air circulation will favor the production of bright stock. In erecting the pile all means by which air circulation may be increased should be considered. These are height of foundations; spacing between boards in a course; thickness, width, and kind of crossers; flues; "chimneys"; vents; horizontal openings; size of piles; spacing between adjacent piles; selection of ground for yard sites. Yard location and drainage are also important factors influencing the rate of drying.

The boards showing the heaviest staining are usually found in the courses of the lower central part of the pile. The problem, then, is to devise for each particular mill yard and region the combination of factors which will insure ventilation of this portion of the pile with the minimum of expense and lost space.

The crosser itself presents a problem. (See fig. 31.) Old, moldy crossers are bound to carry sap-stain infection to the freshly piled boards by spore or thread contagion. Heartwood crossers are preferable to sapwood crossers of a species of wood different from and less susceptible to sap stain than that which is being piled, or of sizes which are readily marketed so that they need be used for only one season and may then be sold.

Piling practice plays an important part in the success or failure of such blue-stain preventive methods as preliminary heat treatment by steaming and the use of various chemical dips. If improper piling follows, there is every reason to believe that the beneficial effects of the heat or chemical will be greatly reduced, if not entirely lost.

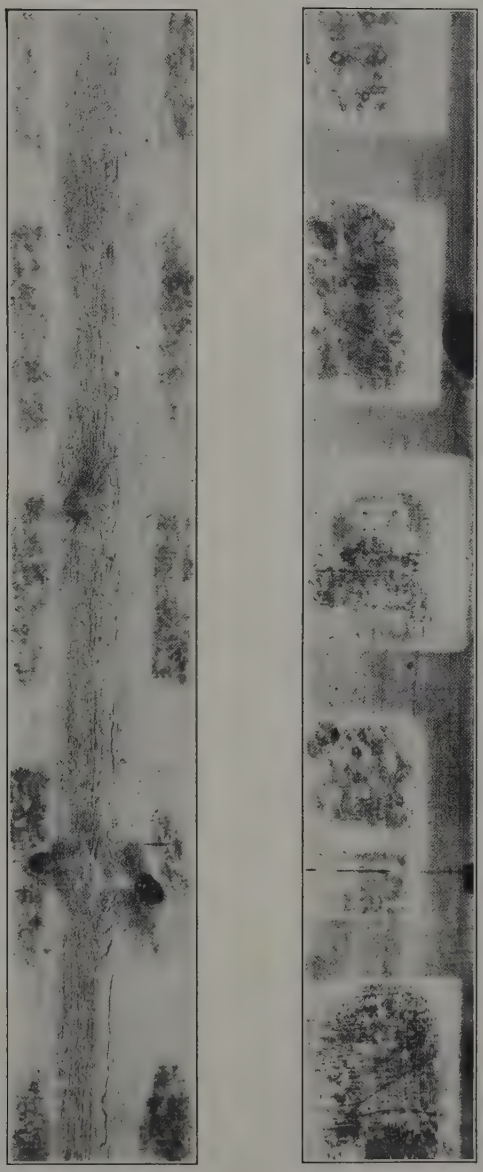

FIGURE 31.—Heavy blue stain, or crosser stain, in western yellow pine lumber used as crossers in a pile of the same size and grade of stock

In planning for the best piling practice there is one further consideration that must not be overlooked. Where checking and other defects due to air-seasoning become serious, care must be taken to pile the lumber so that too-rapid drying shall not take place. A balance is required between rapid drying to prevent sap stain and too-rapid drying which may result in excessive checking. Both checking and sap-stain losses should be reduced to a minimum, and these somewhat opposing requirements add to the difficulty of the problem.

BETTER PILING PREVENTS WASTE

That the loss due to blue stain is a drain on our forest resources is not always recognized, but when one considers the fact that

FIGURE 32.—View taken in the air-seasoning yard of a southern hardwood mill. The methods of piling used here are of the type that produce rapid drying and a minimum of sap stain. Note the high open foundations and the narrow piles

potentially high-grade lumber is reduced to lower grades through stain it is easy to see that an increased supply of the best logs is needed to fill the gap thus formed. Necessarily, a more rapid depletion of our forests follows, along with an overproduction of lower, less easily marketed grades of lumber. In an analysis of air-seasoning data to be presented later, it will be shown that better piling methods greatly reduce the amount of sap stain appearing in lumber. (Fig. 32.) Such a result points the way to scientific piling as a means of cutting down the annual blue-stain loss, increasing the proportion of high-grade lumber from the log, and assisting directly in the conservation of our timber supply.

Proper piling practice is a matter of locally applying the principles involved to the particular problems encountered. In some regions

blue stain overshadows the other seasoning defects and must be dealt with accordingly. Again, end checks may be the major defect that needs to be eliminated, or two or more defects may appear in sufficient amounts to warrant special piling. Conditions influencing air-drying vary greatly within the same region, and with the wide variations of climate, topography, mill practices, and wood species to be found in the United States it is impossible to present any specific rules for preventing sap stain. Since blue-stain fungi are tiny plants greatly dependent upon water for their development, the rapid removal of moisture from the surfaces of sapwood lumber during the first few days of air-seasoning is the process underlying the successful prevention of sap stain. To accomplish this the circulation of air over the green boards must be rapid to carry away the necessary moisture but not so rapid as to cause end checks and center checks to appear in the lumber. The problem then becomes one in which the circulation of air through the pile and the removal of moisture-laden air from the lower part of the pile must be carefully regulated to meet local conditions. Since the general movement of air in a pile during the early period of seasoning is downward,[48] [49] [50] the height of foundations, topography of ground, and amount of weed growth must be taken into account in order to get this soggy air drained away from the piles. Increasing the foundation heights will be of no avail unless care is taken to control the weeds.

EFFECT OF WEEDS IN THE LUMBER YARD

Weeds or any kind of rank growth in the yard where lumber is seasoning usually mean a reduction of the air circulation under the lumber piles and an increase in moisture about the base of the pile. These conditions encourage blue stain in the lumber and may also slow down the drying rate within the piles. Weeds give an untidy appearance to the best of yards and should be removed to prevent their spread. In the late summer and in the fall, or whenever the vegetation begins to turn brown and becomes dry, a large weed crop represents a serious fire risk in any yard and should not be tolerated. The slogan, "Everybody loses when timber burns," applies to the wood in a lumberyard as well as to the green timber in the forest.

There are several ways in which weeds may be kept down or eradicated in the lumberyard. Cultivation of the area or mowing with a scythe are out of the question, since the weeds and grasses growing closely about the pile foundations can not easily be reached by either of these methods. Grazing the area regularly with sheep or other stock has been successful at several plants. Treating with chemicals presents a practical method that has much in its favor. Common salt is among the more common and less expensive chemicals and is usually applied at the rate of 50 to 75 gallons per acre, using 150 pounds of common salt to 50 gallons of water. For the broad-leaved plants a solution made up of 100 pounds of iron sulphate to 52 gallons of water is often used and sprayed on the plants

[48] Fullaway, S. V., jr., and Hubert, E. E., The Air-Seasoning of Lumber in the Inland Empire: Timberman 26; April, 1925.
[49] Green, C. B., The Air-Seasoning of Lumber in the California Pine and Redwood Regions: Timberman 26; October, 1925.
[50] Johnson, H. M., and Gibbons, W. H., The Air-Seasoning of Lumber in the Douglas Fir Region: Timberman 27; October, 1926.

while the leaves are still young and tender. This chemical, however, does not kill all the noxious plants and often kills only the tops, the roots remaining alive and producing new shoots.

Sodium arsenite, 2 pounds to 52 gallons of water, is very effective, although it is a very poisonous chemical to handle, and care must be used in applying it where stock may feed on the treated plants.

Another chemical recommended as a positive killer of many weeds is carbon bisulphide, but this is rather expensive, costing about $1.25 per gallon. This chemical is applied to the roots of the plants by means of small holes 18 inches deep and 2 feet apart each way, filled with 2 ounces of the chemical. A gallon of the chemical will treat about 200 square feet. The chemical should be applied when the soil is quite moist. Care must be exercised in handling this liquid, as it is very inflammable. Many other "weed killers" may be found on the market and tried out for their effectiveness in disposing of plant growth in the lumber seasoning or storage yards.

OUTLINE OF PILING PRACTICES

In order to present to the reader the many variables that may be used in improving the piling practice, with particular reference to the prevention of blue stain, a condensed outline has been prepared from a review of the various articles recently published on air seasoning.[51] [52] [53] [54] The yard superintendent can study the outline and select such variables in piling practice as will best fit the local conditions. Special attention is called to four publications issued by the National Committee on Wood Utilization, of the Department of Commerce, Washington, D. C., in which seasoning, handling, and piling problems are discussed in minute detail. Four reports have been printed treating these matters as they affect consumers, distributors, fabricators, and sawmill operators. The title of each of these reports is shown on page 11 of this report under the heading of Publications of the National Committee on Wood Utilization.

YARD AND PILING PRACTICE TO REDUCE STAIN

YARD LAYOUT

Drainage, slope. Proper drainage for both air and water.
Exposure to sun and to prevailing winds.
Nearness to rivers, lakes, swamps. Affects drying rate.
"Hog fuel" fills not desirable.
Direction of alleys. (North and south.)
Width of alleys—varies from 16 to 20 feet.
Cross alleys every 200 to 500 feet.
Spacing between piles should be continuous and about 4 feet wide.
Blocking of alleys and spaces between piles should be avoided.
Spacing between rear of piles should be about 10 feet.

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[51] Fullaway, S. V., jr., and Hubert, E. E., The Air-Seasoning of Lumber in the Inland Empire: Timberman 26; April, 1925.
[52] Green, C. B., The Air-Seasoning of Lumber in the California Pine and Redwood Regions: Timberman 26; October, 1925.
[53] Johnson, H. M., and Gibbons, W. H., The Air-Seasoning of Lumber in the Douglas Fir Region: Timberman 27; October, 1926.
[54] Newins, H. S., The Proper Piling of Lumber: Southern Lumberman 121: 185–188; December, 1925.

HANDLING BEFORE SEASONING

Avoid long bulking of green stock before transportation to yard.
Keep free from dirt.
Use cover boards on uncompleted piles.
Chemical dip.
Steaming.

YARD TRANSPORTATION

Avoid bulk piling of green lumber before placing in piles.
Plank driveways, trams *v.* metal tracks.
Sanitation of yard. Removal of all infected wood.
Removal of weeds. Increases circulation, reduces fire hazard.

PILING METHODS

General.—Type of pile (square in softwoods, narrow in hardwoods).
Size of pile (60 to 100 courses).
Pitch, slope.
Parallel to or right angles to alley.
Roof construction. Water-tight.
Roof overhang, front, rear, and sides.
Drip boards. (Not always effective.)
Overlap of crossers. Useful in reducing end checks.
Random length stock (box piles).
Random width stock.
Insufficient foundations and crossers cause sag.
Pile foundations (18 to 24 inches *clear* at rear).
Crossers.—
Size, number (three crossers to 16-foot stock).
Kind (heartwood, new, clean, dry, and narrow).
Condition (kiln-dry, rough, not too old). Old crossers carry spores.
Overlap (2 to 4 inches for 4 to 8-inch stock). Prevents end checks.
Storage (off the ground; keep dry and clean).
Stock crossers (cause crosser stain, checks, etc.).
Opening up the pile (center, lower third of pile usually shows greatest stain).—
Foundation heights.
Crosser heights (thickness).
Thick crossers or double crossers in lower pile.
Spacing between boards in a course. (Fig. 33.)
Chimneys (the use of three 8-inch, one 12-inch, or of single, flared chimneys).
Horizontal openings in lower part of pile.
Boards edge to edge, several chimneys.
Roofs. Raised above top of pile.
Seasonal methods.
Special methods.—
End coatings (to prevent stain, decay, and checks in logs and thick plank stock).

Wrapping or poultice method for thick plank stock.
Chemical dips.
Steam-box treatment, Kraetzer cured.

HANDLING AFTER SEASONING

Avoid unpiling or transporting in rain or snow.
Keep free of dirt.
Canvas covers for truck loads exposed to weather.
Adequate roofing over transportation channels from yard to planer, to storage shed, to shipping dock.

FIGURE 33.—An example of one of the many ways in which methods of piling in the yard may favor the development of sap stain. In this pile the spaces between boards in the same course are irregular and at the top the circulation is cut off by the overlapping of the two top boards. Note the sap stain on the ends of the sap gum boards

Sanitation of storage sheds.—
Foundation timbers and floors must be dry.
Ventilation needed to remove moisture in shed.
Prevent leaky roofs.
Do not store damp lumber.

Loading of freight cars.—
Thoroughly clean the car.
Add layer of clean sawdust.
Add a number of clean wood strips.
Protect lumber from rain, snow, and condensation of moisture within car. (Even kiln-dried stock, though sterilized by heat, must be protected from moisture to prevent reinfection. Inclose a placard with each shipment, telling dealer how best to care for the stock in order to avoid staining, warping, checking, etc.)

There are two special methods used in the seasoning of lumber which have not been previously described in this bulletin and which need a word or two of explanation on account of their uniqueness. These methods are the end racking of green hardwood lumber practiced in the Southern States and the wrapping or poultice method of piling thick plank stock used to a limited extent in the Western States.

END-RACKING

This method consists of piling hardwood lumber on edge in racks in the form of the letter X. Sometimes this method of piling is called pole-piling and is used principally as a preliminary step in regular air-seasoning practice. The rate of drying is greatly increased under normal conditions by this method, and sap stain is prevented. After the boards have remained in these racks for several days they are placed in regular piles to complete the seasoning. The disadvantages of this method are the large amount of space needed for piling, additional handling costs, and a considerable amount of cup and warp. End checks frequently develop at the upper ends of the boards, and this is sometimes prevented by crossing the boards at the top instead of some distance down from the top. Care must also be exercised to keep the bottoms of the boards off the ground in order to prevent decay and stain. Due to the exposure of the stock to the weather, end-racking must be carefully watched and adjusted to local weather conditions. This practice is used in drying yellow poplar, basswood, cottonwood, sap maple and sap gum.

POULTICE-PILING

The poultice or wrapping method of piling lumber for seasoning is used to a limited extent in drying thick plank stock of the higher grades cut from pine sapwood. Pattern stock cut from western white pine is handled by this method, which consists of wrapping the two faces of each plank with 4/4 western red cedar heartwood. The planks and their layers of cedar boards are separated from each other by crossers. (Fig. 34.) The pile is often boarded up at front and rear to reduce end-checking. In some cases each plank has both ends coated with a layer of paraffin to reduce end-checking. The paraffin is applied hot by means of a special spraying apparatus and serves as a very effective end coating.

A study made of this method of piling indicated that the cedar boards not only aided in slowing down the drying rate and thus prevented the formation of center checks but the toxic water soluble or volatile constituents of these boards were found to be effective in preventing sap stain from developing in the thick sapwood planks.

The use of unseasoned stock of species other than cedar for wrapping material was observed to have resulted in severe staining of the planks. Old cedar boards previously used for crossers or carrying considerable blue-stain infection are not as effective as new thoroughly dried boards.

More recently cedar boards have been used successfully in wrapping thick sapwood stock undergoing seasoning in the kiln. The

drying schedule used with thick stock is usually a mild one, and with low temperatures sap stain and mold may appear on the plank. The cedar boards help to prevent this and also tend to slow down the rate of evaporation of moisture from the plank stock.

THE UTILIZATION OF BLUE-STAINED LUMBER

Blue stain in sap lumber is not a stage of decay. Although it is the work of fungi, it leaves the strength of the wood practically unimpaired for ordinary purposes. Nevertheless it is an object of natural suspicion and a source of large degrade losses. Proper kiln-drying is the only completely effective method now known of preventing blue stain. In spite of years of experience with chemical

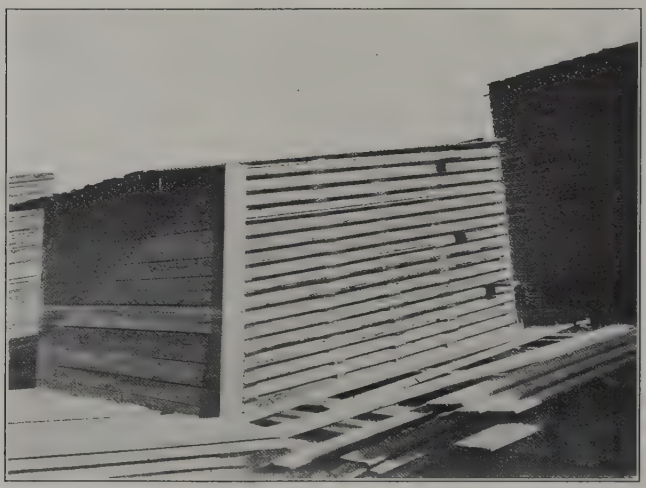

FIGURE 34.—A pile of 10/4-inch western white pine plank undergoing seasoning by the poultice method. Note the layers of inch cedar boards on the upper and lower faces of the planks. The front and rear ends of the pile are boarded up to prevent end checking

dips, nothing has yet been found which will give consistent results during the warm rainy season. Until a practicable, effective method of prevention is found for cases where kiln-drying is not feasible, proper utilization of blued stock will remain the only way of reducing the loss from this source.

The utilization of blue-stained wood must, however, be undertaken intelligently. In the first place, kiln-dried material should be chosen in preference to air-dried, for the reason that decay-producing organisms, as well as stain fungi, are more likely to be killed in the former. Secondly, before recommending the use of blued lumber, whether air-dried or kiln-dried, the holder of such stock should assure himself that it has not become infected with decay-producing fungi in addition to the blue stain. The recognition of decay associ-

ated with sap stains is difficult, particularly when decay is in the early stages or when the staining is very heavy.[55]

Since wood destroyers thrive under conditions which favor the bluing of wood (fig. 35), heavily stained material should be examined carefully for signs of decay. If this is done and specific uses are suggested by the dealer, a greater confidence in decay-free blued stock will result.

Blue stain is freely accepted in rough lumber, lath, scantling, plank, and some of the larger sizes of dimension. More could well

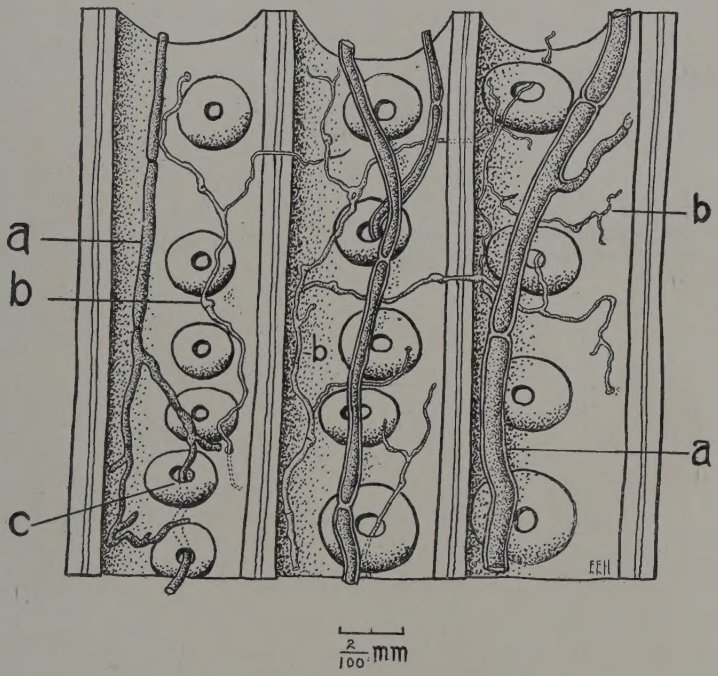

FIGURE 35.—Drawing of a section of Sitka spruce sapwood as seen under the microscope showing the large threads *a* of a blue-stain fungus and the smaller threads *b* of a wood-rot fungus in the wood cells. Conditions for the growth of both types of fungi were present in this material. Note how the blue-stain threads pass through the natural openings in the cell wall at *c*, while the rot-producing threads bore their way through the walls

be used, where sapwood is not objectionable, in the manufacture of frames, sash, doors, trim, finish, millwork, and other products, when the discolored wood is to be painted or otherwise hidden from view.

As blemish in any degree would destroy the beauty of the grain of the wood, bright, stain-free stock is highly desirable for a large variety of uses requiring a natural finish. But for many purposes where the wood is to be covered, stained, or painted, and where conditions of exposure permit the use of sapwood, there is no reason for

[55] Forest Products Laboratory Technical Note No. 184.

discriminating against blued stock if it is free of decay. The following list of present or suggested uses for blue-stained material is to be applied under the restrictions stated above and according to best judgment in each case:

Automobile and vehicle parts.
Boxes and crates.
Car construction.
Casings and baseboard.
Caskets and coffins.
Ceiling.
Concrete forms.
Core stock.
Doors.
Falsework.
Finish.
Furniture and case goods.
Joists.
Lath.
Partition.
Patterns and flasks.
Paving blocks.
Picture frames, moldings.
Rafters.
Rail and balusters.
Sash.
Scaffolding.
Screens and screen doors.
Sheathing.
Shelving.
Stairs and stepping.
Structural timbers.
Studding.
Subflooring.
Toys and turnings.

While the utilization of blued stock is recommended with certain limitations, it must be remembered that the practical solution of the problem lies in finding efficient methods of preventing the blemishes caused by these mold organisms rather than in allowing the blemishes to appear and later finding uses for stained wood.

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